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DEPARTMENT OF THE AIR FORCE

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AFIT/GEM/LSM/90S-9

A PERFORMANCE ANALYSIS
OF THE USAF
WORK INFORMATION MANAGEMENT SYSTEM

THESIS

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# A PERFORMANCE ANALYSIS

# OF THE USAF

# WORK INFORMATION MANAGEMENT SYSTEM

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Engineering Management

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## Preface

The purpose of this research is to collect and analyze information relating to system performance of the Work Information Management System (WIMS). The data are analyzed to provide a description of current performance conditions, to establish a baseline for future comparisons, and to determine or confirm relationships between performance related variables.

The research shows large system memory and unfixed Sharer buffers are strongly related to better performing systems. Other relationships are described. A list of suggested parameter settings is provided. Recommendations for future research in this area are presented.

In conducting this research, I received considerable assistance from others. I wish to thank Mr Ed Fink of HQ Air Force Logistics Command for providing access to his computer system and his knowledge. The information and advice he provided was invaluable. The completion of this thesis would have been nearly impossible without his assistance. Special thanks also goes to Capt Earl Warner and Mr Harley Parvin of Eglin AFB. The review and comments they provided on the questionnaire greatly improved its quality. Finally, I would like to thank my thesis advisor, Lt Col James Holt, for introducing me to this topic area and providing valuable guidance.

Reno T. Lippold

## Table of Contents

## List of Figures

## List of Tables

Table | Page

AFIT/GEM/LSM/90S-9


## Abstract

The purpose of this ~~research~~ is to collect and analyze information relating to system performance of the Work Information Management System (WIMS). Information on system performance analysis and tuning is consolidated by means of literature review and interviews of experts. A combination tutorial and questionnaire is developed to collect the data. Two new measurement techniques are developed.

Data are collected and summarized on system performance knowledge and involvement in the field. Data are collected on system parameter settings and configuration, external factors related to system performance, and levels of system performance.

The data are analyzed to provide a description of current performance conditions, to establish a baseline for future comparisons, and to determine or confirm relationships between performance related variables. Relationships between system performance and other variables are emphasized.

Information is collected in fifteen areas of performance from forty-two bases.

The research shows larger system memory and unfixed Sharer buffers are strongly related to better system performance.

A list of suggested parameter settings is provided. Recommendations for future research in this area are presented.

A PERFORMANCE ANALYSIS

OF THE USAF

WORK INFORMATION MANAGEMENT SYSTEM

# I. Introduction

## Background

USAF CE is responsible for air base facility construction, maintenance, and repair. Construction involves new facilities or alterations. Maintenance encompasses such work as painting, snow removal, and roofing. Repair work includes correcting broken water lines or pot holes in roads. This is a $4 billion dollar per year business. The size and complexity of operations in CE lends itself well to automation of data management (7:8).

The first major computer system used by CE was the Base Engineer Automated Management System (BEAMS). It first came on line at the base level in the late 1960s. BEAMS is limited and very inflexible. Modifications to the database and reports are very difficult to make and data in the system generally lag actual conditions by several days. By the mid 1970s, senior management in CE became convinced that a much more flexible system was needed. A completely new concept for data automation within CE was created. This new concept lead to the development of the Work Information Management System (WIMS). A prototype test of WIMS was first conducted at Tinker AFB in September of 1983 (30:4-5). In the spring of 1986, Wang Corporation was awarded a

contract to provide the hardware for the computer systems (7:8). Most software was written by Air Force teams. Currently, over 100 USAF bases have WIMS installed and operating on the Wang (19). WIMS is the new computer system standard for CE and will eventually replace BEAMS (13:1-3).

Since its inception, the scope of WIMS has greatly expanded. WIMS was originally intended for job order management - a significant, but small part of CE's information processing needs. Later, this scope grew to include work orders, contract projects, word processing, real property management, supply management, telecommunications, and many others. Today's WIMS contains approximately 2000 programs and 500 major data files (10). The increase in scope has created a need for greater user access. Original installation plans called for a VS100 with 30 work stations for each base. This grew to 60 and eventually to 128 work stations (the maximum available for the system at the time). This rapid change in scope and use has resulted in a system workload far greater than originally planned (16, 28).

## Problem

Lt Col James Holt, of the Air Force Institute of Technology, feels the WIMS computers are running at less than optimum performance levels (10). Capt Thomas Lavery, in his 1988 thesis, found "many users complained that the WIMS was too slow and took too long to perform most procedures" (13:44). Additionally, Major Barry Wentland, of the Air Force Engineering and Services Center, said Base Civil Engineers often complain of excessive response times (28). Little information exists on

how we use these computer systems and how they are performing. Ideas for improvement are based largely on speculation.

## Purpose

The purpose of this research is to analyze WIMS and its environment, to determine if changes could and should be made to user training, system hardware, system software, and operating guidance to improve the performance of the computer systems and enhance the productivity of CE.

Investigative Questions. To complete this research, the following specific questions must be answered. Each is numbered for later reference.

Response and Processing Times. (1) What is the nature of processing times and delays occurring in the system during normal operation? (2) How much productive time is lost due to computer delays?

User Concerns. (3) How do the system users feel about system performance? (4) How important is performance to the users?

Knowledge of System Performance Issues. (5) How knowledgeable are our SAs about system performance analysis and tuning?

Performance Work Effort. (6) How involved are our SAs with system performance analysis and tuning work?

Factors Affecting System Performance. (7) What are the factors that affect system performance and how significant is each?

Performance Analysis and Tuning Software. (8) What type of performance analysis and tuning software is available and being used? (9) How beneficial are these products?

Productivity Enhancements. (10) What changes to system hardware, software, or training would improve system performance?

## Justification

Many knowledgeable Civil Engineers indicated that research of this type has never been conducted on the WIMS. (1, 6, 8, 10, 11, 12, 16, 28) This research could be used to develop changes in user training, system hardware, software, or standard operating procedures. Implementing the recommended changes should result in performance improvement of the USAF WIMS which would allow more effective use of computer assets and increase the productivity of USAF Civil Engineering.

## Scope of Research

This research is restricted to WIMS system performance issues. This study does not address software or hardware problems or enhancements not relating to system performance. Training is considered only to the extent that it is related to system performance. Efficiency of software run on WIMS is not addressed.

## Assumptions

This work assumes the performance of a computer system is dependent on variables which can be identified and measured.

## Definitions, Acronyms, and Abbreviations

Term definitions and explanations of abbreviations and acronyms can be found at Appendix A.

## II. Literature Review

### Sources of Information

Information on Wang VS system performance can be obtained from four sources - Wang manuals, experts, Wang related periodicals, and Air Force documents. System performance information specific to a WIMS environment can be obtained only from expert sources and Air Force documents.

Wang Manuals. Wang Inc publishes a wide ınge of manuals for their computers. These manuals cover topics such as the operating system, data management system, programming, and operator's information. Two manuals, VS System Performance Guidelines (Parts I and II), are devoted entirely to system performance issues. VS System Performance Guidelines Part I, contains a wealth of information on performance issues but is limited in usefulness. It is written for an advanced operator - someone who is already familiar with terms and advanced concepts associated with the Wang VS. It does not cover all performance issues. It is written in a very general manner and so cannot be directly applied to a WIMS. These problems limit this manual's usefulness as an information source for WIMS SAs. In general, the other Wang manuals seem well written and should be useable by the average WIMS SA. However, information on system performance is dispersed among these manuals and cannot be located easily. Also, the information is written to apply to a wide range of computer environments and cannot be directly applied to a WIMS.

Experts. Some SAs have picked up a wealth of knowledge about system performance over time. This knowledge comes from readings,

formal instruction, discussions with other SAs, and personal experience. Expert advice is the primary source of information on WIMS system performance. The information available from the WIMS experts is based on their experience in a WIMS environment which is an significant advantage over other sources. Information from experts is valuable but is also of limited use to a SA. The information is not documented in most cases and so is not readily shared. A given expert generally has knowledge in only a few areas of system performance and so many experts would have to be consulted to get comprehensive coverage. Expert opinions are often based on one time successes and not on systematic research. As a result, this information may not be generalizable to systems beyond the ones dealt with by the expert. Information often conflicts from one expert to another. Further, little data exist to backup claims.

Periodicals. Periodicals are another source of information on system performance. Access to Wang is a magazine that periodically features articles on Wang VS performance. These articles are primarily written by experts and are based on their personal experiences. This written information is readily disseminated but otherwise suffers from the same disadvantages as expert sources described previously. Additionally, these experts are basing their ideas on non-WIMS environments.

USAF Documents. USAF agencies, such as MAJCOMS and the AFESC, have written documents on WIMS performance. One reviewed was written by AFESC (reference 29). It contains a few brief comments on system performance.

Taken together, these sources provide a wealth of information, but a SA looking for information on Wang VS system performance would have to consult many sources and piece the information together. No comprehensive documentation was located covering Wang VS system performance in a WIMS environment.

## The Wang VS

The Wang VS is the hardware component of WIMS. VS stands for 'virtual system' which is a unique method of memory management that allows many interactive tasks to run at once on one computer. Within a VS, the total memory requirement of all running tasks can greatly exceed the actual physical electronic memory (main memory) installed. Disk storage space supplements the main memory (23:1.2). To conserve memory space, two or more users, using the same program, automatically share the program code. Also, data for designated files can be shared (23:1.2). Still, under heavy use, memory demand will normally exceed the size of main memory. Because the CP can work only with information in main memory, each task is serviced in turn and given a limited amount of time in memory by a time sharing algorithm. When this time is up, information associated with the task must be moved from main memory to make room for another task's information. Eventually, processing returns again to the former task and information to continue the program must be read from disk back into memory (22:6.26).

Figure 2-1 shows a simplified one-line diagram of a Wang VS100. Architectures for other models are similar. The lines connecting the block components - CP, memory, IOPs, and the drives - represent communication channels over which information flows.

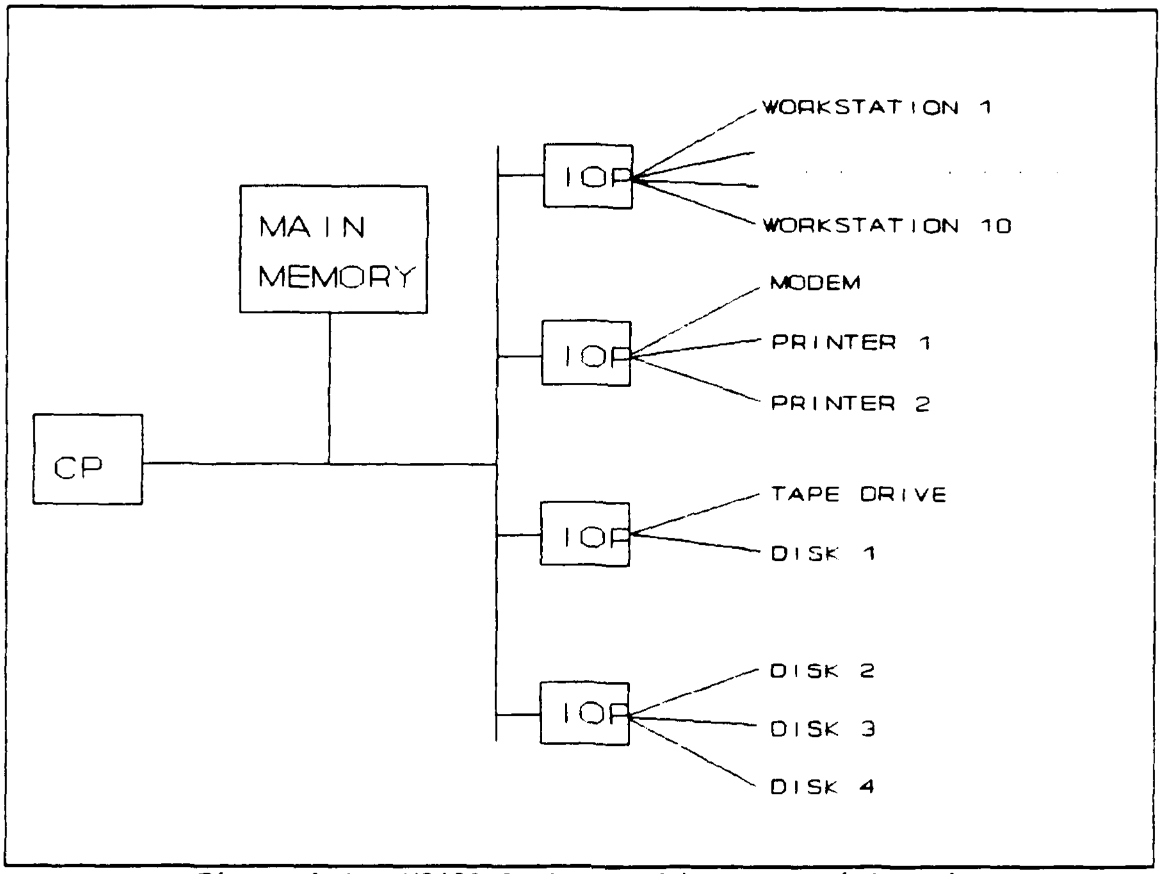



Figure 2-1. VS100 System Architecture (22:1.4)

Many different models of the Wang VS are available. Models VS100 and VS7310 and the 5000 series are the predominant types used within USAF. The VS100 accounts for most of the computers (16).

Factors Affecting System Performance

The performance of a specific computer is a function of many interrelated factors. The workload makes demands on the system resources. A complex functional relationship of the workload and resources determines the resulting system performance. This thesis examines factors affecting system performance (for example, VTOC I/O rate is a factor). In each case, the factor is described and its affect

on system performance is examined. Measuring and controlling the factors is discussed. Rules-of-thumb for parameter settings (example: VTOC cache size) which affect the factor are presented if known. Finally, cautions and tradeoffs associated with parameter modifications are discussed. Appendix B contains a summary of standard measurement methods for both factors and parameters. Appendix C contains a detailed tutorial on measurement and interpretation of system performance factors.

Workload. The term 'workload' describes the tasks directed to the computer. It is a function of the number of users working on the system and the type and quantity of work done. Workload is a very important determinant of system performance. For a give system configuration, each component of the computer system has a maximum capacity for work. It the work requested exceeds this capacity, large internal queues will develop and system performance will degrade significantly. The workload on a computer typically varies over time. A daily variation is normally quite prominent. For a WIMS, the workload is generally considered to be heavy in the morning when workers are first arriving and tappers off later in the day (15). Execution of resource intensive programs can have a big impact on the level of workload at any given time. For WIMS, the following individual tasks are believed to be heavy resource users (3, 27).

(1) CEMAS end-of-day processing

(2) BEAMS to WIMS processing

(3) WIMS to BEAMS processing

(4) BACKUP processing

(5) RESTORE processing

(6) BCAS processing

Many SAs believe that word processing heavily loads a system because of high frequency of use (16).

The workload on a computer system can be measured by examining the underlying factors which affect it. The number of users working on the system is one such factor. The programs running and their functions improve the picture. Finally, the amount of work done (the amount of data processed and the frequency the action is requested) completes the picture (5:38).

Several options are available for controlling the workload on a computer system. The workload could be reduced by eliminating some work. This could be done by restricting use of the computer by reducing the number of users or by reducing the type and frequency of work requested. This would normally be considered an extreme action and is rarely practiced. Still, it may be possible to identify unneeded work and eliminate it. The workload can be rescheduled to reduce peak periods where system performance suffers most. For WIMS, a low use period is off duty hours when few people are at work. This is an ideal time to accomplish individual high resource demand tasks such as those previously listed. Some organizations do schedule this work at off duty hours, but this requires a night shift. Another option, also available to an organization, is to reduce the load on a single computer by shifting some of the workload to an additional computer. For example, some organizations have purchased a VS5000 specifically to handle CEMAS

processing. Besides the obvious problem of the additional computer expense, additional computers greatly increase the SA workload (15).

System Resource Demand. A computer uses its resources to accomplish the workload. The resources may be classified as CP, main memory, I/O channels, and data storage.

CP. A computer's CP executes program instructions which normally involves some manipulation of data. For a Wang VS, many tasks may be executing together, however, only one task may have access to the CP at any one time. A time sharing algorithm apportions CP time to the tasks. If the number of tasks is large and processing requirements are lengthy, queues could develop. Since little can be done to increase the speed at which instructions are processed, it is necessary to reduce or reschedule work to eliminate a CP overload. With the Wang VS, it is possible to give individual programs higher priority for the CP resource. This will improve the response of this program but will degrade overall system performance (26:2.26). An extreme solution would be to purchase a computer with greater CP processing power. Before such an expensive action, one should ensure that the CP is truly the limiting factor in the system. It may be that in a heavily loaded, poor performing system, the CP is often sitting idle while waiting for completion of I/O operations (5:279). Unfortunately, measurement of CP loading is not possible with standard tools.

Main Memory. Memory is an important resource for any computer but is of particular importance for a VS. More memory means that more tasks and data may be in main memory at any time. This means less paging I/O which will normally improve performance. The amount of

memory in a system can be determined through the Operator's Console. It is generally assumed that increasing memory will improve system performance, but some SAs, who have increased their system's memory, report little performance improvement (15). There is not a clear consensus on this matter. It may be that additional memory is not being put to proper use to reduce I/Os or that other factors are limiting performance. "Quite commonly, you will find that there is a substantial amount of memory available - it's just not being used very well (14:B10)." The VS100 is limited to 16 MB and the VS7310 has a limit of 32 MB (16). Memory for a Wang VS costs approximately $1000 for each MB (15).

I/O. I/O involves an exchange of information between memory and a peripheral device. There are many different kinds of I/O. Figure 2-2 provides one classification scheme for I/O on a Wang VS. Most information found relating I/O to performance was about disk I/O - the primary type of parallel I/O.

Disk I/O. When a Wang VS needs information, it looks to memory to determine if the information is resident. If not, the information must be read from disk (assuming the information does not come from a work station or telecommunications port). To make room for this additional information, information already in memory must be written over. Information modified while in memory must be written back to a disk for temporary or permanent storage. Each occurrence of information being written to or read from a disk is called a 'disk I/O operation' or simply 'disk I/O' for short. "Disk I/O's are performance-costly because they operate at mechanical speeds for arm movement and

Parallel I/O

- Disk I/O

-- Paging I/O

--- User I/O
---- page-ins
---- page-outs

--- System I/O
---- page-ins
---- page-outs

-- VTOC I/O

-- Data I/O (File I/O)

--- shared I/O

--- non-shared I/O

Serial I/O

- Telecommunications I/O

- Work station I/O

- Printer I/O

Figure 2-2. I/O Classification Scheme (26:2.17-2.23)

[disk] rotation (14:B7)." Access time to main memory is around 1 microsecond. Access time to the disk is generally from 10 to 100 milliseconds or about 50000 times longer (5:278). It is therefore highly desirable to reduce disk I/Os in a computer system to improve performance. With a given workload and memory size, this is done by optimizing the use of the memory resource to increase the probability that information is located in main memory when needed. Of secondary importance to reducing disk I/O, is minimizing the impact the I/Os have on performance (14:B8). Minimization of impact involves distributing the I/O among disks and IOPs and improving disk performance. Eliminating disk I/O will be covered first followed by I/O distribution.

Improving disk performance is examined later. Disk I/Os can be categorized into three types - paging I/O, VTOC I/O, and data I/O.

Paging I/O. Paging I/O involves moving program code between disk and main memory. When a program is first initiated, its object code must be moved from disk into memory. This code can be thought of as the instructions written in a language such as COBOL or BASIC (the actual code used is converted into machine language or object code). Depending on the size and memory availability, the entire program or only a portion will be loaded. As the program executes, the CP looks into memory for the code needed. If the code needed is not resident, additional code must be read in from disk and stored in place of other code. Programs also establish an area in memory called the MDA (22:6-26). This area holds modified program code. As an example, consider a program which reads in a value "A" from the keyboard, multiplies it by 10, stores the result in "B", and displays the value of "B". The program instructions would look like:

```
2998 ACCEPT A
2999 B = 10 * A
3000 DISPLAY B
```

The actual instructions are non-modifiable code. The values for A and B, however, are modifiable program data associated with the code and would be stored in the MDA. If the main memory time sharing algorithm interrupts the program before completion, the place in the program is marked, and the nonmodifiable code is simply written over with other program code. It can be later read back from the original object code file. The modified code, however, must be written to disk or else this information would be lost (6).

Modified program code is written to a temporary file called a 'paging file' or a special location on disk called a 'page pool'. Later, when the memory time sharing algorithm decides to continue execution of this program, the program code, including at least line 3000, would be read into main memory and all the modified program code would also be read in and placed in a reestablished MDA. Program execution would then continue from this point. This reading and writing of program code and modified program data is called paging and the associated I/Os then are paging I/Os. The rate of paging I/O is an important factor for performance. One SA uses 10 paging I/Os per second as a desired upper bound (14:B9).

Little information was found on measurement of paging I/O with standard tools. The Show Program Completion Report and Show Program Status screens of the Command Processor and Operator's Console provide information on paging for specific program, however, this cannot be transformed into a system paging rate. The POOLSTAT utility provides a "reference rate" for each page pool which could possibly be used to measure the paging rate (24:7.1-7.3). It is not clear exactly what this "reference rate" means and paging to or from other disk files and paging files would not be included in the figures. Performance analysis software, such as SAM, is needed to measure paging rates (14:B9).

Paging I/O can be reduced in several ways. The workload causing the I/O may be rescheduled or reduced. Memory size may be increased. Finally, programs can be examined for linking techniques

that cause unnecessary paging. Paging caused in this way cannot be reduced by adding memory (14:B9).

VTOC I/O. When a Wang VS looks for information on a disk, it must first find the location of that information by reading in location information from the VTOC - an area on the outer edge of each disk. This causes VTOC I/O. This I/O requirement adds to the total time required to retrieve the information. If many read operations are occurring, the total increase in response times can be significant. The Wang VS has the capability to store VTOC information in memory - where it can be accessed more rapidly. The area in memory set aside to hold this information is called a VTOC cache. Information most recently read from a disk VTOC is placed in this cache. If it gets full, older VTOC information is written over by new. When ever a program needs information from a disk, it looks to the VTOC cache first to see if the file location data it needs are there. If it is, it comes from the cache thus preventing an I/O. The larger the VTOC cache, the more VTOC information that can be stored there, and the more likely information will be in it when needed (21:2.5).

The VTOC cache is established automatically during the system initial program load (IPL). The VTOC cache size can be determined by examining the system configuration file using the GENEDIT utility. The size of the cache is described by the number of buffers assigned. A buffer is a 2 kB block of memory. The Systems Options screen of Operator's Console provides information on the VTOC cache 'hits' and 'misses'. A hit is one occurrence of the system finding the information it needs in the cache. A miss represents one occurrence of

a VTOC I/O. The figures given are cumulative and the numbers reset when they reach 65535. Two statistics are available from this information that provide a means to evaluate the impact of VTOC I/Os and the effectiveness of the VTOC cache. The first is the miss rate which is the change in the number of misses divided by the change in time. A rule of thumb used by one SA is to keep the miss rate below 4 per second if possible (14:B10). Another statistic of some use is the hit ratio. This is the ratio of hits to the number of times VTOC information was needed. The total tries is the sum of the hits and misses. The hit ratio provides a number between 0 and 1 whicn describes the portion of times information is found in the cache. In general, the higher the ratio, the better. One Wang manual recommends a ratio of 0.9 as a target (26:2.2). Some believe this is unrealistically high for a WIMS environment (27). The hit ratio does not provide an accurate indication of the miss rate - and this is what really impacts performance. Thus the miss rate should be used in lieu of the hit ratio when possible.

The VTOC cache size can be modified by changing the number of buffers using the GENEDIT utility (29, 21:2.5). Increasing the VTOC cache size reduces the amount of memory available to store program code and data. This reduction of space may reduce performance in these areas (26:2-20). The optimum point of balance must be sought.

<u>Data I/O</u>. The term 'data', as used in this document, refers to information programs operate on. Examples are names and training due dates in a data base file or text in a word processing document. Data needed by a program are retrieved from disk storage and placed in data buffers in memory. When modified data are removed from

memory, they must be written back to a disk. These I/Os are called Data I/Os. The number of data buffers used for a program can be modified to have an impact on data I/O. Data buffers can be categorized as shared and non-shared.

Buffers for Non-Shared Data. Data are stored in memory in areas called buffers. Data which only one program uses at one time are called non-shared data. Conversely, data that can be accessed by more than one task at one time are called shared data. The number of data buffers determines the amount of data retrieved and stored in main memory at one time. When a program needs data, it looks in the data buffers first. If the data are there, they are used or modified. If the data are not in memory, they must be retrieved. The retrieved data are written into memory over the data currently in the buffers. If the old data have been modified while in memory, they are first written out to disk. The number of data buffers established for one program can have a big affect on the performance of that program which can affect overall system performance.

For non-shared data, data buffers are established when a program is initiated. Two different buffering strategies are available. The quantity of buffers is determined by the program code. Therefore, this is a programming matter and is not realistically within the control of the local SAs unless the SAs are capable of making modifications to their software (20:9.3-9.7).

Data buffering is automatic for data files opened in the shared mode. Shared files can be accessed by more than one task simultaneously. Access to shared files is controlled through a program

called SHARER. By allowing shared use, only one copy of the data has to be in memory so memory space and, possibly, I/O operations are saved. An area in memory is set aside to hold this shared data and is called the 'SHARER buffer pool'. Shared data most recently used are placed in the pool. If it gets full, older data are over written by new. When a program needs shared data, it looks to the SHARER buffer pool first to see if the data it needs are there. If they are, it takes them from the pool thus preventing an I/O. This saves time. The larger the SHARER buffer pool, the more data that can be stored there, and the more likely data will be in the pool when needed. The SHARER buffer pool can be set to have the buffers and control blocks fixed or unfixed. Unfixed memory may be shared with other competing demands (26:2-15). The SHARER is a program that interfaces users and programs with data. As it provides an additional layer of processing for a transaction, it will be slower than the same transaction occurring with non-shared memory. Apparently the SHARER only provides performance enhancement on a system basis - not on individual programs (6).

Information on SHARER activity can be obtained through the SHRSTAT utility. SHRSTAT provides a large amount of information including hit and miss counts. As with the VTOC cache, the miss rate and hit ratio can be calculated from these figures. Again the miss rate is the most important statistic. The SHARER buffer pool is established automatically during the system IPL. The number of buffers assigned to the pool and can be determined through the System Options screen of the Operator's Console or by the SHRSTAT utility. Configuration information comes from SHRSTAT.

The SHARER buffer pool size and configuration can be modified by changing settings in the system configuration file using the GENEDIT utility (24.8.1). GENEDIT has a minor bug in that the number of buffers requested is doubled on the actual system. The maximum number of buffers allowed is 255 (resulting in 510 created) (29, 26:2.13). A rule-of-thumb used by one SA is to add Sharer buffers if the miss rate is greater than 5 misses per second (14:B9). Another SA recommends maximizing the number of buffers for a WIMS. Some believe that WIMS runs faster with unfixed buffers. However, if a system is memory rich, fixing the buffers may be the best choice. Shared file operations will speed up with fixed buffers. It is generally considered best to fix control blocks. They take up little memory space and little is gained by freeing them for other tasks (26:2-17, 18).

Increasing the buffer pool size should improve the performance of operations using shared data files - at least to a point. However, this increase reduces the amount of memory available for other tasks and may slow them. This is especially true if the buffers are fixed. (26:2.15)

<u>I/O Distribution</u>. Performance can be unnecessarily degraded if a situation exits where some disks and IOPs are rarely used while others are servicing many I/Os resulting in large I/O queues. Distributing the I/O load among the disks reduces this problem. Unfortunately, the measurement of these queues is not possible with standard tools. Balancing is done by distributing active libraries among the disks, distributing paging I/O, and balancing the disks across the IOPs. If large I/O queues still exist after I/O reduction, I/O

distribution and disk tuning, then additional drives are needed or the workload must be modified. Special software packages are available that can measure I/O load and queues to a particular disk (14:B11).

I/O Errors. Information transferred through I/O channels undergoes error checking. If an error occurs, the I/O must be repeated until the information is transmitted successfully. An error which is "resolved" by further attempts is called a 'soft error'. Soft errors may occur several times before the system stops trying and issues a "hard error' message which means the information could not be properly transmitted. A hard error will stop program execution. Soft errors slow the system because of the extra time required to complete the I/O. The type and frequency of I/O errors is recorded by the system in the I/O error log - a data file maintained by the system (24:3.2-3.9). No information was found to provide a basis for determining if the I/O error rate is excessive.

Data Storage Concerns. In a VS, the disk drives serve as long term storage devices and short term storage for work, spool, and paging files. In the latter case, the disks serve as extensions of memory. As such, they can become a major bottleneck if the overall I/O rate is high and is spread over few disks. It is very important to keep the drives operating at maximum efficiency. Factors which affect the ability of disks to access and read or write information are the disk's speed, file fragmentation and block splitting, disk fault tolerance settings, and file placement. Disk efficiency is indirectly affected by free disk space and page pool management.

Drive Speed. Disk drive speed is determined by two parameters - the access time and transfer rate. The access time refers to the speed at which the read-write head can move to a position to begin reading data. An approximate value for disks currently in use for WIMS is 25 milliseconds. The transfer rate is the rate, in bytes per second, that data are transferred once the head reaches the data location. This is primarily determined by the disk's speed of revolution. Both parameters improve with newer or more expensive technology. The access time is considered to be a prime limiting factor in the rate at which a disk can access data.

Fragmentation and Block Splitting. When a file is stored on a disk it may often get split up into pieces. When a file is broken up on a disk it is said to be fragmented. The different pieces of the files are called extents. When many files are fragmented, performance can degrade. Head seek time from the current extent to the VTOC and then to the next extent causes most of the additional delay (27). Likewise free space on your disk can get fragmented into small chunks. This also degrades performance by slowing the writing of new or expanded files. Generally, if your free space is fragmented, your actual files will be fragmented also (6).

Fragmentation of individual files can be assessed using the LISTVTOC utility and displaying a file list. Information on free space fragmentation is available through the Manage Files/Libraries function of the Command Processor. Keeping free extents under 10 per disk is desirable but is difficult to maintain. Some SAs use 20 as a

desirable maximum (13). Several SAs consider 100 free extents on a 288 MB drive as an acceptable upper bound (14:B10, 3).

Fragmentation of a disk can be reduced in two ways. Running the Compress-In-Place (CIP) utility can solve the problem partially (25:14.1-14.5). Some SAs have had problems with CIP (27). The best solution is to run a full BACKUP and RESTORE on the disk. This consolidates both file and free extents (23). These operations are time consuming and can also impact system performance.

When the system attempts to put information in a block that is too full, the block must split. This means that half of the information is moved to a new block at the end of the file's extent. For indexed files, this complicates the indices and may slow subsequent reading and writing of data. No information was found on measuring the extent of block splitting and little on its significance concerning system performance.

Available Free Space. Disks which become too full can indirectly cause performance problems. When the free space on a dynamic disk gets low, file fragmentation becomes more common and average seek time will increase (14:B10). The solution, of course, is to create more free space. In some cases the only solution may be to purchase additional disk storage. This is normally considered a last resort and other methods are used when practical. Free space on a disk can be assessed using the DISKUSE utility or by the LISTVTOC utility. The following are options to increase available disk space.

(1) Archive unused data.

(2) Delete software or data that is rarely used. Store it on tape or separate disk and reload as the need arises.

(3) Use the COPY utility with REORG parameter on data files to delete records that are marked for deletion.

(4) Reduce the size of your page pools if they are excessively large. More information can be found later under page pool management.

(5) Use compressed files with 100% packing factor for infrequently modified data files or files that normally have records added only to the end of the file.

(6) Libraries can be moved to different disks.

A disk over 80% full is generally considered too full. Higher percentages are increasingly serious (27).

<u>File Packing Factors and Compression</u>. There are many different ways to store a file on disk. A popular method with large files is to store them compressed and with a 100 percent packing factor. In this mode all blank fields in each record are reduced and as many records as possible are stored into a block of disk storage space. The file takes up the least amount of disk space and provides very fast access - initially.

Unfortunately, this method may cause performance problems as the file is updated. If a record is added in the middle of the file (based on the primary key) or if blank fields are filled in, there will be no place to put this information. The block will split and in many cases the file will fragment. Block splits and file fragmentation complicate indexes resulting in slower access and update operations. Additionally, because of the way the system allocates

additional extents, the amount of disk space allocated to the file will grow (22:2-12).

A better method may be to store the file as compressed but with data packing factor less than 100% - perhaps 85%. This will provide some room for expansion for filling in fields and reduce the rate of fragmentation. Using this method will require more disk space initially. Another alternative would be to store the disk as uncompressed with a 100% packing factor. This would leave space for all the blank fields. If many fields are never used, this could waste disk space (6, 24, 20:9.1). It is not currently known if this idea could improve WIMS performance.

A file's current packing factor or compression setting can be determined or changed during a copy operation. Settings can also be made when the file is initially allocated. The setting stays with the file unless changed later (6). Two packing factors must be entered. One is for the data (DPACK) and one is for the indexes (IPACK). Since fewer changes are normally anticipated with the indexes than the data, the packing factor for the indexes can be higher (example: 95% if the data packing factor is 85%) (20).

Eventually, any file may develop block splits and become fragmented. COPY with REORG will fix the block splits and reestablish the growth space allocated according to the packing factor (and delete records marked for deletion).

Disk Fault Tolerance Settings. If the VTOC becomes damaged, data may be lost in some or all of the files on the disk. To guard against such losses, the Wang VS has the capability to maintain

more than one VTOC. If one is damaged, the others can than be used to get the location information. This protection feature is determined by the disk fault tolerance setting.

There are three levels of protection. No setting provides one VTOC. The next level is called 'crash' and provides two VTOCs. The highest protection is called 'media' and provides four VTOCs, two pairs on separate cylinders (22:6.21). While the higher protection may seem desirable, there is a price to be paid in performance as you go up in protection level. When you make a change to a file, the VTOC will often need to be updated. Any VTOC modifications must be made to each VTOC in turn. More VTOCs means more time to complete file modifications and also more disk space consumed (6).

Media tolerance has the VTOC information on separate cylinders, therefore, disk head movements are necessary to update all the VTOCs. This means a significant difference in modification times between media and crash. Crash protection provides two VTOCs, but they are on the same cylinder and the information is interleaved meaning modification time should be only slightly higher than for no protection. Crash protection is generally considered adequate. If a system is on UPS (power loss is one cause of VTOC damage) and/or daily backups are conducted, no VTOC protection may be needed. Apparently little can be gained in performance by going from crash to no protection (27, 22:6.22). The chief advantage may be to free up disk space. A disk which is primarily used for static files and temporary files (work files, paging files, and spooling files) would be a good candidate for no protection. A disk with little file alteration activity would have

few VTOC alterations and thus little would be gained by lowering the protection. Performance gains can only be made by lowering protection on disks with changing files.

A disk's protection level is set by the system administrator during initialization using the DISKINIT utility. The current settings of each disk can be found through the Operator's Console by selecting Manage Disks, (PF10).

File Placement. When information is retrieved from or written to a disk, the read-write heads in the disk drive must move to the proper cylinder from the location of the last file accessed. This physical movement takes considerable time (relative to other computer operations) and the farther apart the two files (or two extents of the same file) the more time consumed. To speed up this operation, it is desirable to have the most active files close together on the disk. Since the VTOC must reside on the disk's outer edge and is also frequently accessed, it is generally advantageous to put the most active files close to the VTOC. Conversely, inactive files, such as COBOL source code, should be displaced away from the active region toward the center of the disk. Page pools are accessed very frequently and would also be best placed near the outer disk edge. By collocating active files, disk throughput can be increased by as much as 50% (14:B12).

The SA can identify and reposition files on disk to take advantage of this performance factor. The DISKMAP useraid can be used to determine file location on disk. Apparently, some WIMS do not have this utility. Frequently accessed files can be identified by looking in the interactive task screen in Operator's Console over a period of time.

The names of the frequently used files will becoma familiar quickly (27). Repositioning files can be accomplished during a RESTORE operation by first manually restoring desired libraries closest to the VTOC and then the remaining libraries using the NOCOPY option (23). This whole process is fairly time consuming but is essentially a one time requirement. Once the libraries are placed near the VTOC, they stay there through backups and restores.

Page Pool Management. Page pools must be properly sized to avoid impact on system performance. If page pools are too small, pages will be forced to go to paging files and performance will degrade. Conversely oversized page pools can consume valuable disk space which can indirectly affect system performance. An understanding of the purpose and function of page pools is necessary to properly manage them.

This process of transferring information back and forth between disk and memory is called 'paging'. When modified portions of a program are paged out to disk they are put into a temporary location or paging area. This paging area can be a page pool or a paging file (22:6.26).

Precise definition of terms is essential to communicating the concepts. In this document the words 'individual page pool' refer to a single page pool on a disk. The words 'system page pool' refer to the individual page pools as a collective system. The words 'page pool' refer to either concept. Two additional key terms are 'commitment' and 'physical usage' which describe two very different concepts and must not be confused. Commitment, sometimes called 'memory commitment' refers to the amount of modifiable data assigned to a page pool. This modifiable

data represents potential (not actual) data. It is expressed as MB or as a percentage of the page pool capacity. If the maximum amount is assigned, the page pool is said to be fully committed. Physical usage (or utilization) refers to the amount of actual data stored in a page pool. This is expressed as MB or as a percentage of the page pool capacity.

If many users are working on the system, paging activity may be heavy. Under these conditions paging can have a great impact on system performance. Modified information is written to an individual page pool if one exists and if the pool is not already fully committed to other tasks. Otherwise, the modified data will be temporarily stored in paging files which are automatically created by the system. This is undesirable from a performance standpoint because these files may be located at many different points on the disk and are often fragmented. Paging files require more time to create and recover compared to their counterparts located in a paging pool. Ideally then, the page pool should have capacity to satisfy all users. The system administrator can control the size, number, and location of individual page pools (22:6.26-6.32).

Two important parameters in page pool management are the page pool commitment ratio (CR) and the user modifiable data area (MDA). The commitment ratio determines how many users will be assigned to an individual page pool before it is fully committed. The CR is system wide and applies to all users. The default setting is 400% - one recommendation is to set it at 250% (29:5). The MDA is the maximum amount of modifiable data allowed per user in memory or in an individual

page pool. The system default MDA is assigned by GENEDIT. Individual users can have different amounts assigned through SECURITY or VSSECURE. Both parameters can be controlled by the SA. The following equation shows the relationships of these variables:

$$MUAIPP = IPPS*CR/MDA \tag{1}$$

where

MUAIPP = Maximum users assigned to an individual page pool

CR = commitment ratio (2 not 200%)

MDA = modifiable data area (MB)

IPPS = individual page pool size (MB)

An example illustrates this relationship. A system has one 10 MB page pool, the commitment ratio is 4 (400%), and the MDA for all users is 1 MB. Then the maximum number of users (tasks) that can be assigned to this page pool would be $10 * 4 / 1 = 40$ . Running more than 40 tasks would require the use of paging files instead of the page pool with a resulting deterioration in performance. Note that with 40 tasks the page pool is fully committed but will only be partially utilized (full of data) at any given time. This is because each task will generally only use a fraction of the 1 MB MDA allotted. In fact, with a commitment ratio of 4, each task can use at most 25% of their MDA (on the average) or the page pool will fill up. If a page pool becomes fully utilized (fills with data), the system may crash. A page pool can be 100% committed but should never be allowed to become more than 75% utilized (to allow some margin for error). A Wang VS provides warning errors if a page pool fills to near 100% physical usage; however, no

messages are displayed if all individual page pools become fully committed. The existence of paging files implies that one or more individual page pools are fully committed. Paging files are stored in library @SYSPOOL (22:6.27-6.33).

From equation 1, it can be seen that the number of tasks that can be assigned to the page pool can be increased by (1) increasing the page pool size (larger individual page pools or more of them), (2) increasing the commitment ratio, or (3) decreasing the MDA for the tasks.

When setting up a page pool scheme, the location of the individual page pools on disk, size of the individual page pools, size of the system page pool, and disks selected to have page pools should be considered. Space for a individual page pool is established by the DISKINIT utility. A page pool does not receive pages unless the disk it is on is enabled for paging. The disks enabled can be controlled through Manage Devices of the Command Processor.

Location on the disk. The individual page pools are frequently accessed and should be placed near the busiest part of the disk. In general, the page pools should be placed on the outer portion of the disk near the VTOC. The location of a page pool is specified through the DISKINIT utility. The location of an existing page pool can be found with the DISKMAP utility. Page pools are in library @SYSPOOL in file @POOL@ (22:6.30).

Size of Page Pools. The system page pool must be large enough to service the normal maximum loads but not so large that disk space is wasted. When first creating a system page pool it is wise

to make it large and then monitor the usage with POOLSTAT. The size can later be reduced, by reducing individual page pool size, through the Relabel function of DISKINIT. Increasing the size later is difficult. (22:6.31)

Location among disks. For a VS, paging accounts for much of the I/O to and from the disks that are enabled for paging. In general, several disks should be enabled for paging and, to a lesser degree of importance, the disks enabled should be distributed among the IOPs. The system disk (normally SYS001) must have a page pool enabled or system paging will go to paging files. One SA recommends page pools on all disks (18). The decision on number and placement of page pools can best be made with a complete evaluation of I/O activity on the system.

Page pool parameters and activity can be monitored with the POOLSTAT utility (24:7.1-7.3)

FASTLINK. The FASTLINK utility keeps specified files permanently open. Properly used, this feature can improve system performance. When a task issues a command to open a file (starting a program or manipulating a data file), the system must locate the file by examining the VTOC and must allocate control blocks for the file. This takes time. If a file is opened frequently, the access speed will be improved for that file if it is kept permanently open. FASTLINK can only be used with program files. It works best on files that are used frequently but remain open for short time intervals. An example of such a file could be the DISPLAY utility. Normally, it would be run by a user for a short time to obtain some quick information. If it is being

used many times during the day, it would be a candidate for FASTLINK. Infrequently used programs such as BACKUP would not be good selections for FASTLINK. Also, programs, such as Wang WP (word processing), that are used often but are run for a long time by each user would generally not benefit from FASTLINK. (24:2.1-2.15, 27)

Files for FASTLINK can be found by selecting possible candidates, including them in FASTLINK, and monitoring them over time. Those that do not have the proper characteristics could be deleted, leaving those that do. FASTLINK is best suited for files that are frequently used. In addition to high usage, the files should be used for short periods. Usage can be determined by inspection of the Display Perm-Open Files screen of the FASTLINK utility. If the file normally displays 0 or 1 active users, then it is probably used for only short periods. If it also has high usage, then it is a good candidate for FASTLINK (24:2.1-2.15).

No rules-of-thumb were found for determining what is meant by "high usage". Additionally, no guidance was found for the best files to be used in FASTLINK on a WIMS.

Keeping a file open consumes a small amount of memory, even if the file is not being used. If many such files are permanently open, the amount of memory that is tied up may become significant. This memory could be used to satisfy other demands for memory. Also, you will not be able to delete, patch, or rename any permanently opened files or dismount a volume that has permanently opened files on it (24:2-14).

The Wang Utility manual (23) contains an excellent discussion of FASTLINK and selecting files for its application.

Software Efficiency. How a software package is written can be a big factor in determining the efficiency at which it runs. WIMS utilizes software from several sources. WIMS software is the core and is written by the AFESC. Another big software system is CEMAS. This and PDC (programming, design, and construction) were written by the Air Force standard software center at Gunter AFB (16). Generally, the more sophisticated the software, the slower it runs. Newer versions of Wang OFFICE are thought to be much slower. Some feel WIMS or CEMAS software could be speed enhanced. This change, if possible, may come only with tradeoffs in other areas such as flexibility or power. This area may hold some important clues for improving the performance of WIMS but was not included in this research (3, 10, 11 12).

Training/Resources. An important factor in system performance is the training and resources of the operators and managers. A computer cannot function on its own. Without constant attention and work from trained people, system performance will degrade rapidly. For organizations that do not have the manning or expertise to perform their own performance analysis work, consulting firms are available. Performance analysis services cost at least $3000.

Priorities and Rules-of-Thumb. One thing characteristically absent from this discussion and from other sources is information on the relative priorities of each of the system performance factors and rules-of-thumb for parameter settings. There is little to help an SA establish a good starting point. Few rules-of-thumb are published by

Wang. This is probably because the environments where their computers are used vary widely. One particular parameter setting may work well in one environment but actually degrade performance in another. The same type of reasoning has been used to describe the problem for WIMS. However, it should be pointed out, that in AF CE, we are dealing with systems that use nearly identical software and process very similar kinds of data in very similar ways. With these factors in common, it seems reasonable that general rules-of-thumb could be developed that would provide settings allowing operation in an environment close to optimum.

Performance Analysis/Tuning Software

The preceding discussions consider the performance analysis and tuning resources that are available to most SAs (standard tools). It is common that information needed for performance analysis is not extractible from the computer system by readily available means. Further, tuning work is often complex and very time consuming. Special software packages exist that assist in these matters. The following is a brief summary of the packages currently on the market in this category.

System Activity Monitor (SAM). SAM is a performance analysis package. It was developed by Wang Inc and is specifically designed to monitor internal operations and produce statistics. In the right hands it can reportedly be a powerful package. The resulting information requires expert interpretation. The package tells you what is happening but does not indicate if this is good or bad or what to do to improve performance (16).

Wang On-line Resource Management Tool (WORM). WORM is a performance analysis package produced by Wang Labs of Australia. It provides data similar to that available with POOLSTAT and SHRSTAT utilities and also includes information on CP utilization, disk utilization, and service calls. It does not identify problem areas nor suggest improvements or solutions (9). The data provided requires considerable technical knowledge for interpretation.

VS Space. VS Space is a file management program that performs file reorganization, consolidates free extents, reestablishes packing factors, and works file placement. It is produced by an independent software firm. This package also comes with a system response monitor program that can monitor the response times of some system activities (6).

Other packages available are Space Saver and System Minder which perform functions similar to VS Space.

## Measurement of System Performance

To accurately assess the performance of a computer system, the performance should be quantified. A number which describes the performance of computer system is called a performance index. An accurate quantification of performance could be used to:

(1) monitor the performance of your system over time to determine if performance is improving or degrading.

(2) make a quantifiable comparison of your system performance before and after making a change to hardware, software, operations, or configuration. Changes in performance may be small and undetectable without measurements in many cases.

(3) provide numbers that could be used to compare your system to other similar systems. If another similar system had a significantly better or worse performance index, you could then look for factors to explain the difference.

(4) Provide numbers that could provide economic evaluation or justification for performance improvement alternatives.

Several methods are available to measure performance. Benchmark loads can be run on the computer. A benchmark is normally considered a set of programs and commands that simulates a real workload. The completion time of the benchmark would provide a measure of the system performance of that workload. The benchmark could be run before and after system modifications to measure change in system performance. The benchmark has the advantage of providing an identical workload to the computer for testing; however, the system must be off line to perform the test. Another technique would be to run only one or several tasks on a system and measure their response or turnaround times. The programs would be run during normal computer operations. This techniques has the disadvantage that computer workload, and resulting test times, may vary widely from moment to moment. This problem can be compensated for by running the program several times over a period of time and using statistical methods to obtain one performance index (5:9-141).

Performance indexes have been used with WIMS. The 2750 ABW (Air Base Wing) Civil Engineers, at Wright Patterson AFB OH, are monitoring long term system performance as part of an organizational test. To develop their performance index, they time five different functions on

their WIMS - logging on, logging off, job order addition, labor update, and material issue. Each function is timed seven times daily at the same time each day. The high and low values are dropped and the remaining values are averaged. The resulting averages are plotted on a control chart (one for each function) to expose changes over time. They plan to change the daily checks to random checks (2).

User Satisfaction and Impact

Before investing significant time and resources, the SA working performance issues should examine the impact to the users due to the computer's speed. The results of this assessment will provide a means to assess the severity of the problem and properly prioritize work in this area. The impact data would provide justification for expenditures of time and money to improve performance and develop a means to quantify the value of improvements in performance. A assessment of impact to users could be made by observing a sample of users; however, this would be time consuming. A survey could be conducted, where the users as asked questions that measure how they feel about system performance and the impact it has on their jobs. The survey could include all users or a sample of the users as long as the sample is randomly selected and large enough to ensure that the answers are representative of the organization in general.

Costs of Performance Improvement

Performance improvement does not come free. Personnel conducting the analysis and tuning work will require training. Training may result in TDY (temporary duty) expenses and possibly school fees. Local in-

house training will require manuals and training aids. Regardless of the method, training will require a considerable time investment. Depending on the level of effort desired, performance analysis software may be needed to collect the data. Data collection will be time consuming. The data collected will require analysis. Tuning actions will require expertise, time, and in some cases contracted assistance from Wang Corporation or other sources. Hardware purchases will be needed in some cases (5:485-488, 14:B7).

# III. Methodology

## Overview

This chapter describes the research method. It begins with a description of the population of interest and identification of variables. Next, the sampling design and data collection methods are presented. Finally, the data analysis is covered.

## Population of Interest

The population of interest for this research is all USAF WIMS. This population also contains many subpopulations such as the USAF WIMS using a Wang VS100 computer or all USAF WIMS on TAC bases.

Variables and Measurements. Chapter II describes each variable which is suspected or known to affect system performance. Appendix D contains a summary of these variables. Measurement of performance variables is made with tools normally available (standard) on a WIMS with two exceptions.

No standard tool exists to measure the performance of a WIMS. The time to compile a standard COBOL source code file is used in this research to obtain a performance measure. The compile operation is run nine times during a duty day, and the results are averaged. The resulting times provide a measure of system performance.

No standard tool is available to measure the amount of queueing for disk I/Os. A program was written to provide a measure of these queues. The program is at appendix G. The program writes and erases a file ten times to each disk and calculates the average time to

write the file for each disk. This average time gives an indication of the extent of the I/O queue for the disks.

Sampling Design

The value of population parameters can be estimated from sample data. "The basic idea of sampling is that some of the elements in a population provide useful information on the entire population" (4: 276). In the case of WIMS, there is a finite and relatively small number of cases from which to obtain data - approximately 130 systems total. The decision was made to sample the entire population of bases in the United States with a WIMS. This resulted in 79 questionnaires sent. Overseas bases, Alaska, and Hawaii are excluded primarily due to probable communication problems and perceived differences in operating environments. Variance estimates are made from the data obtained, and the precision is published for each statistical result.

Data Collection

A questionnaire to obtain information on performance variables is at appendix C. The questionnaire requests base demographic information and both qualitative and quantitative data relating to system performance. It also includes a tutorial on performance. The questionnaire collects a broad range of information. To reduce the burden on those who complete it, the questionnaire is broken into several parts for completion by randomly selected bases.

A letter with the questionnaire attached was sent to the Base Civil Engineers (BCEs) at each selected base requesting they complete the questionnaire. The questionnaire includes detailed instructions

explaining how the local WIMS will be used as the tool for collecting the data. Existing software was run on the WIMS by the local SAs to provide the information needed. The observations are conducted at time intervals and periods selected using consistent random methods to avoid bias in the results.

Mail surveys are versatile and can be used to obtain abstract or subjective information which could not be obtained by the computer. A disadvantage is that the respondents may not have the knowledge to respond or may not interpret a question correctly.

The success of a mail questionnaire depends heavily on the cooperation of the BCEs and the SAs at the bases. The following details are included with the survey to improve the chances of cooperation and response. The cover letter is signed by the Dean of the School of Systems and Logistics. The letter and questionnaire contain an explicit deadline for providing the data. Return envelopes are provided. The questionnaire is written to also function as a tutorial on performance thus providing an incentive for the SA to complete it.

## Data Analysis

Data provided by the questionnaire are analyzed to answer the research questions. Numeric data are analyzed using both descriptive and inferential statistics. The primary analysis tool is Statistix 2.0, a statistical analysis package written for personal computers. Confidence intervals are obtained using MathCad 2.5.

Descriptive Statistics. Descriptive statistics are used to summarize and display data. The mean provides an indication of the central tendency, and the variance describes how widely the data values

vary. The descriptive data serve several purposes. First, it may be possible to draw inferences and develop insights about the processes affecting WIMS performance simply by examining this information. Secondly, this information would be useful for development of hypotheses which could be tested under this or later research. Finally, this information provides a baseline of information for future reference. Follow on research results could be compared with this information to determine if changes are occurring over time.

Inferential Statistics. Inferential statistics are used to test hypotheses and estimate parameters. Three types of inferential analysis are performed on the data.

Inferences on a Population Mean. Hypothesis testing is used to draw an inference about a parameter of the population - such as the mean. As an example, one could estimate the average level of knowledge in an area of system performance. The mean of a sample provides a point estimate of the true mean; however, it does not indicate how close the estimate is to the true value. Confidence intervals provide a way to address this issue. To construct a confidence interval, the data must be normally distributed and the variance must be known. If the mean is the parameter of interest and the sample size is large, the sample variance can be used to estimate the true variance, and the distribution of the mean will be approximately normally distributed.

ANOVA. Analysis of Variance (ANOVA) is a statistical testing procedure where samples are tested from two or more different populations to see if the source populations have the same mean. In ANOVA, the dependent variable must be at least interval level, but the

independent can be as low as nominal. The dependent variables must have equal variances. As an example, ANOVA is used to test if system performance is significantly different for different user commands.

Linear Regression. Regression is a statistical testing procedure where one makes inferences about the functional relationship between one or several independent variable and a dependent variable. In regression, the dependent variable and the independent variables must be at least interval in general, but two-valued nominal variables can be used as independents also (17). For example, regression could be used to develop the functional relationships between memory size and number of users (independent variables) and system performance (dependent variable). The resulting models could then be used to make predictions about the average performance level expected for a given memory size or number of users. More importantly, the model could yield information about which of the two factors is more critical to system performance (4:396-399).

## Answering the Research Questions

The research questions listed in Chapter I are answered using the above tools.

Question 1. What is the nature of processing times and delays occurring in the system during normal operation? Parts 7 and 8 of the questionnaire provide the data to answer this question. The data for system performance indices and user waiting times are analyzed to produce the means, variances, and high and low values. This provides a description of how waiting times vary from system to system and the means for comparison.

Question 2. How much productive time is lost due to computer delays? Question 3 of the performance survey in Part 8 provides information on user waiting times. The mean waiting time for each base is used to develop an average waiting time for an average user.

Question 3. How do the system users feel about system performance? Question 1 of the performance survey in Part 8 provides information on users' feelings about performance (good or bad). The statistic of primary interest is the overall average with a secondary look at the distribution and variance of the data.

Question 4. How important is performance to the users? Question 2 of the performance survey in Part 8 provides this information. The overall mean and the variance are calculated.

Question 5. How knowledgeable are our SAs about performance analysis and tuning? Parts 7 through 15 contain a question that measures the knowledge of the SA on each specific aspect of performance analysis and tuning. The mean value for each of these is calculated presenting a picture of general knowledge in 9 areas of system performance. Confidence intervals are calculated to better determine the true mean.

Question 6. How involved are our SAs with system performance analysis and tuning work? Similar to question 5, measures are taken on nine aspects of involvement in system performance. Means and confidence intervals are calculated for each aspect and for system performance work overall.

Question 7. What are the factors that affect system performance and how significant is each? The answer to this question is complex and

the work behind it represents a majority of the statistical work done. A master performance index is developed for each base using the objective system performance measure of Part 7 and four other subjective measures. Connections between numerous variables measured by the questionnaire and system performance are sought. Differences based on individual nominal variables such as MAJCOM are explored using ANOVA. The combined affect of interval level variables is explored using simple regression.

Questions 8 - 9. These questions deal with commercially available performance analysis and tuning software. Part 3 of the questionnaire addresses this area. The means and variances of each question for each software product are presented.

# IV. Data Analysis

## Introduction

Of the 79 questionnaires sent, 43 were received. The quality was generally good, but many were only partially complete. Also, several contained information that was obviously incorrect. The result is small sample sizes for many measurement areas. This adversely affects the precision and significance of the statistical results.

Some data provided by the questionnaire are transformed to allow proper statistical analysis. The transformations are at appendix E. This chapter describes the analysis and results associated with each research question.

## Question 1

System delays are evaluated from two measurements. The system performance index (variable SPI) provides one measure. This number is the mean time, in seconds, to compile a standard COBOL source code file (MFACINQ). Table 4-1 provides summary statistics and a histogram of the system performance index results for 36 bases. The data suggest that system delays vary by a factor of five from the worst to the best case. A second measure of system delays comes from the reported individual waiting times. This information comes from the variables WAITx (x = 1..5). These variables provide the number of respondents in a given category of waiting time per day. From this data, a

Table 4-1. Performance Index Statistics

Descriptive Statistics of SPI

| Mean | SD | N | Min | Max |
|---|---|---|---|---|
| 121.7 | 44.96 | 36 | 51.1 | 248 |

Histogram of SPI

| Low | High | N | |
|---|---|---|---|
| 40 | 70 | 3 | *********|
| 70 | 100 | 9 | *************************** |
| 100 | 130 | 14 | ****************************************** |
| 130 | 160 | 4 | ************ |
| 160 | 190 | 2 | ****** |
| 190 | 220 | 2 | ****** |
| 220 | 250 | 2 | ****** |

composite variable MWAIT is created which provides the mean waiting times for a given base. This number is a base specific estimate of how much productive user time per day per user is lost due to computer response delays. Table 4-2 provides summary statistics for the variable MWAIT.

If SPI and MWAIT both measure system delays, they should have a strong positive correlation. Analysis results in a -0.1244 correlation. This implies the variables are not related. MWAIT has a large variance and an erratic distribution. The SAs, who conducted the survey, generally had very low response rates for the questions leading to the data for MWAIT. These observations suggest MWAIT is not an accurate measurement of system delays for a specific base. In contrast, SPI has a smooth lognormal distribution, is

Table 4-2. Mean User Waiting Time Statistics

Descriptive Statistics of MWAIT

| Mean | SD | N | Min | Max |
|---|---|---|---|---|
| 456.8 | 186.6 | 16 | 101.6 | 771.5 |

Histogram of MWAIT

| Low | High | N | |
|---|---|---|---|
| 100 - | 200 | 3 | ¦*************** |
| 200 - | 300 | 0 | ¦ |
| 300 - | 400 | 2 | ¦********** |
| 400 - | 500 | 5 | ¦************************* |
| 500 - | 600 | 1 | ¦***** |
| 600 - | 700 | 4 | ¦******************** |
| 700 - | 800 | 1 | ¦***** |

objectively measured, and was obtained in a consistent manner. SPI is retained as a measure of system delays when comparing one base to another. MWAIT may still provide a reasonable estimate for the magnitude of lost time on an AF wide basis.

Question 2

Lost productive time per base is estimated using the mean of the variable MWAIT. An AF wide estimate is made by averaging MWAIT for all bases. From table 4-2, the mean for MWAIT is 457 seconds per user per day. A 90% confidence interval for the mean is 380 - 534 seconds. An example can put this number in better perspective. For an average CE squadron with 278 computer users, the total daily lost productive time estimate would be

$$457 \text{ sec/day-user} * 278 \text{ users} \div 3600 \text{ sec/hour}$$

$$\approx 35 \text{ hours/day}$$

At an average shop rate of $15 per hour, the value of this lost time is $530 per day or about $160,000 per year per base.

Question 3

Information describing the attitude of users to system performance is obtained with the MUSAT variable. MUSAT is

Table 4-3. User Satisfaction With Performance Statistics

Descriptive Statistics of MUSAT

| Mean | SD | N | Min | Max |
|---|---|---|---|---|
| 2.82 | 0.50 | 16 | 2.06 | 3.94 |

Histogram of MUSAT

| Low High | N | |
|---|---|---|
| 2.0 - 2.3 | 4 | **************** |
| 2.3 - 2.6 | 0 | |
| 2.6 - 2.9 | 5 | ******************** |
| 2.9 - 3.2 | 3 | ************ |
| 3.2 - 3.5 | 3 | ************ |
| 3.5 - 3.8 | 0 | |
| 3.8 - 4.2 | 1 | **** |

the mean of the USATx responses for a given base. Table 4-3 displays descriptive statistics and a histogram for MUSAT. Higher numbers represent greater satisfaction with system performance. The AF mean is close to a neutral position.

However, individual bases have significant differences. One base has a mean response of "satisfied" (4) while four bases report a mean of "dissatisfied" (2).

Question 4

The variables IMPx provide a measure of the importance users place on performance relative to other computer

Table 4-4. Importance of Performance Statistics

Descriptive Statistics of MIMP

| Mean | SD | N | Min | Max |
|---|---|---|---|---|
| 3.41 | 0.52 | 16 | 2.06 | 4.17 |

Histogram of MIMP

```
Low   High   N
1.7 - 2.1    1  | ****
2.1 - 2.5    1  | ****
2.5 - 2.9    0  |
2.9 - 3.3    1  | ****
3.3 - 3.7   10  | ****************************************
3.7 - 4.1    2  | ********
4.1 - 4.5    1  | ****
```

issues. The composite variable MIMP is the mean of the responses for a given base. Table 4-4 provides descriptive statistics and a histogram of this data. Higher numbers represent greater relative importance given to system performance. Note the large number of bases that have means in the range 3.3 to 3.7. This is between "medium" (3) and

"high" (4) importance. The data suggest that users place the issue of system performance higher than a majority of other computer issues.

Question 5

Information on SA knowledge of system performance issues is provided by examining responses to questions specifically focused on knowledge of performance indices, user impact, SHARER analysis, VTOC cache analysis, disk drive analysis, FASTLINK analysis, page pool analysis, I/O bottleneck detection, and file packing factors and compression. Table 4-5 provides descriptive statistics for each of the performance areas examined. Higher numbers represent less knowledge. Since the mean of any random variable is approximately normally distributed (when N is large), and N is large in most cases, confidences intervals based on the normal distribution can be determined. Note that most of the confidence intervals overlap. An exception is the interval for disk drive analysis. This confidence interval is significantly lower than most of the others. This means there is strong evidence the SAs have greater knowledge in this area as compared to the others.

The general knowledge level of the SAs is good. Few indicate the knowledge in the tutorial was new. The statistical results indicate moderate knowledge in nearly all areas of performance.

Table 4-5. Knowledge of Performance Issues Statistics

| Knowledge Area | Var | Mean | SD | N | 90 & 99 % Confidence Intervals |
|---|---|---|---|---|---|
| Performance Indices | PKPI | 3.22 | 1.17 | 36 | 2.9 - 3.5<br>2.7 - 3.7 |
| User Satisfaction and Impact | PKUSIA | 2.88 | 1.09 | 16 | 2.4 - 3.3<br>2.2 - 3.6 |
| SHARER Analysis | PKSA | 3.16 | 0.97 | 19 | 2.8 - 3.5<br>2.6 - 3.8 |
| VTOC Cache Analysis | PKVCA | 3.25 | 1.18 | 16 | 2.8 - 3.7<br>2.5 - 4.0 |
| Disk Drive Analysis | PKDDA | 2.0 | 1.05 | 30 | 1.7 - 2.3<br>1.5 - 2.5 |
| FASTLINK Analysis | PKF | 2.43 | 0.98 | 7 | 1.8 - 3.0<br>1.5 - 3.4 |
| Page Pool Analysis | PKPPA | 2.76 | 1.13 | 21 | 2.4 - 3.2<br>2.1 - 3.4 |
| I/O Bottleneck Detection | PKIOBN | 3.56 | 1.33 | 9 | 2.9 - 4.1<br>2.6 - 4.5 |
| File Packing Fact and Compression | PKPFC | 3.0 | 0.97 | 16 | 2.6 - 3.4<br>2.4 - 3.6 |

Question 6

The effort SAs spend on system performance work (involvement) is measured for the same performance areas as for knowledge. Table 4-6 provides descriptive statistics and confidence intervals for each of the areas. Higher numbers represent greater local involvement. The 90% confidence intervals for VTOC cache, I/O bottleneck, and file packing factors are the only ones completely below 3.

Table 4-6. Performance Analysis and Tuning Effort Statistics

| Area | Var | Mean | SD | N | 90 & 99 % Confidence Intervals |
|---|---|---|---|---|---|
| Performance in General | LIP | 3.12 | 0.91 | 39 | 2.88 - 3.36<br>2.75 - 3.50 |
| Performance Indices | LIPI | 2.78 | 0.99 | 34 | 2.50 - 3.06<br>2.34 - 3.22 |
| User Satisfaction and Impact | LIUSIA | 3.31 | 0.60 | 16 | 3.06 - 3.56<br>2.92 - 3.70 |
| SHARER Analysis | LISA | 2.71 | 0.96 | 19 | 2.35 - 3.07<br>2.14 - 3.28 |
| VTOC Cache Analysis | LIVCA | 2.20 | 0.77 | 15 | 1.87 - 2.53<br>1.69 - 2.71 |
| Disk Drive Analysis | LIDDA | 3.7 | 1.12 | 30 | 3.36 - 4.04<br>3.17 - 4.23 |
| FASTLINK Analysis | LIFA | 3.0 | 0.58 | 7 | 2.64 - 3.36<br>2.44 - 3.57 |
| Page Pool Analysis | LIPPA | 3.0 | 1.0 | 21 | 2.64 - 3.36<br>2.44 - 3.56 |
| I/O Bottleneck Detection | LIIOBNA | 2.22 | 0.97 | 9 | 1.69 - 2.75<br>1.39 - 3.05 |
| File Packing Fact and Compression | LIFPFC | 2.44 | 0.89 | 16 | 2.07 - 2.81<br>1.87 - 3.01 |

This range represents "minor" to "moderate" work. Disk drive analysis has the only interval totally above 3. This range represents greater than average work. This result and that for knowledge indicate emphasis in this area. All other intervals hook 3 ("moderate" work level). In general, SAs are moderately involved in most areas of performance.

<u>Question 7</u>

Relations among system configuration, parameter settings, and system performance are explored in several different ways. System performance is measured with five variables which are combined for the analyses. The variable SPI is the objective measure of performance. Note that higher values of SPI correspond to poorer performance. MPI is a composite variable of four subjective measures of performance (MWAIT, CMPLN, UPOPSA, and SAPERA) and SPI. MPI will be used for the analyses unless otherwise stated.

The distributions of SPI and MPI are checked with a Wilk-Shapiro Rankit plot. Both are found to be approximately normally distributed.

Correlation analysis is run on the five base performance variables. If they measure the same thing, they should be correctly correlated (SPI positively with complaints (CMPLN)). MWAIT is improperly correlated with SPI but correctly correlated with the other variables. It is retained as a partial measure of system performance. The other variables are properly correlated with one another.

The data received contain information on one VS 7310 computer and one computer system that did not run CEMAS software. To increase the homogeneity of the data, these two cases are removed from analysis for this research

question. The remaining 41 cases include only VS 100 computers running both WIMS and CEMAS software.

VTOC Cache Analysis. Table 4-7 displays descriptive statistics for VTOC cache related parameters and a histogram showing the distribution of VTOC cache size. A wide range of VTOC cache sizes are in use with no particular preferences for small or large sizes. Regression analysis does not show VTOC cache size to be linearly related to performance. The impact of the VTOC cache size may be

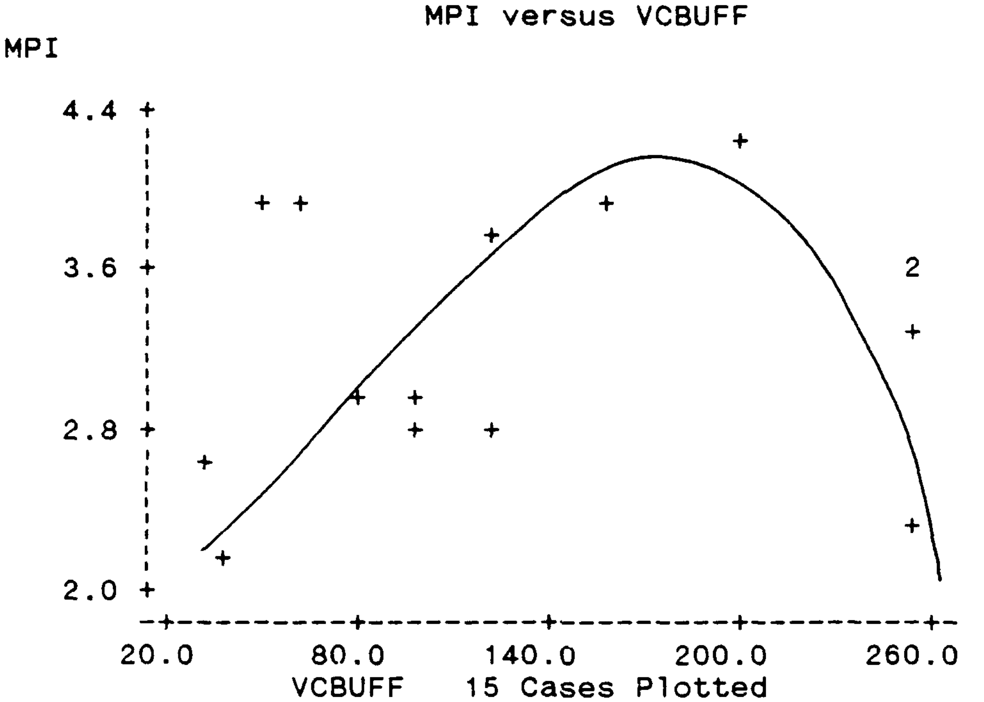
Table 4-7. VTOC Cache Statistics

Descriptive Statistics of VCBUFF, VCHR, VCMR

| Description | Var | Mean | SD | N | Min | Max |
|---|---|---|---|---|---|---|
| Number of VTOC cache buffers | VCBUFF | 138.5 | 84.9 | 15 | 32 | 255 |
| VTOC cache hit ratio | VCHR | .79 | .13 | 13 | 0.55 | 0.95 |
| VTOC cache miss rate | VCMR | 2.27 | 1.9 | 13 | .52 | 5.5 |

Histogram of VCBUFF

```
Low  High   N
  0    40   2  |**************
 40    80   3  |*********************
 80   120   4  |****************************
120   160   1  |*******
  0   200   1  |*******
200   240   0  |
240   280   4  |****************************
```



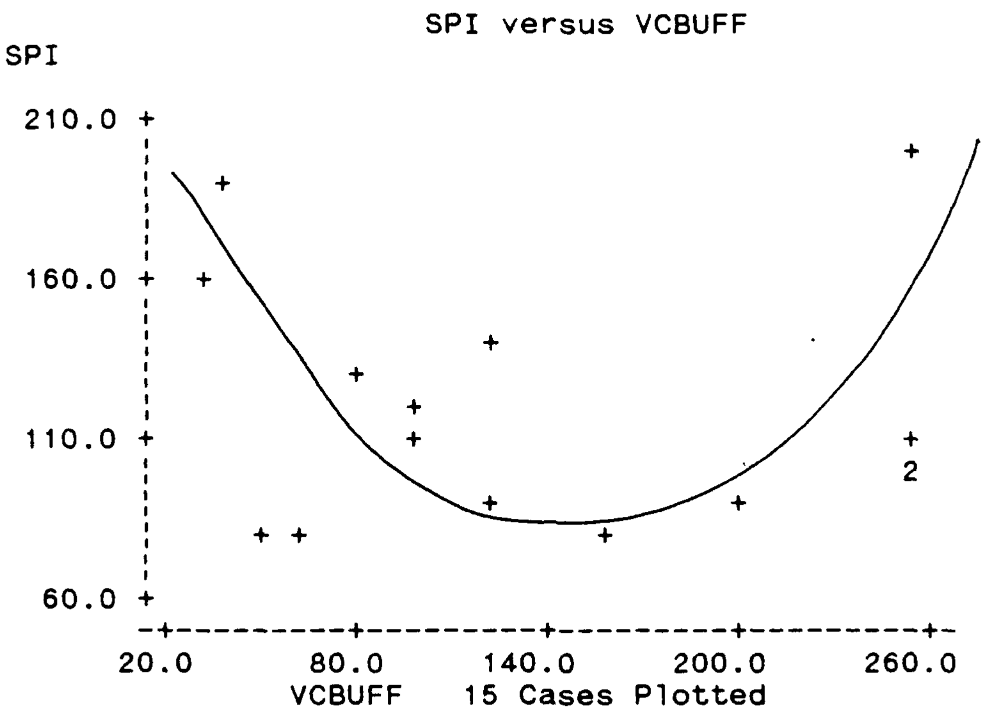




Figure 4-1. Performance Versus VTOC Cache Size

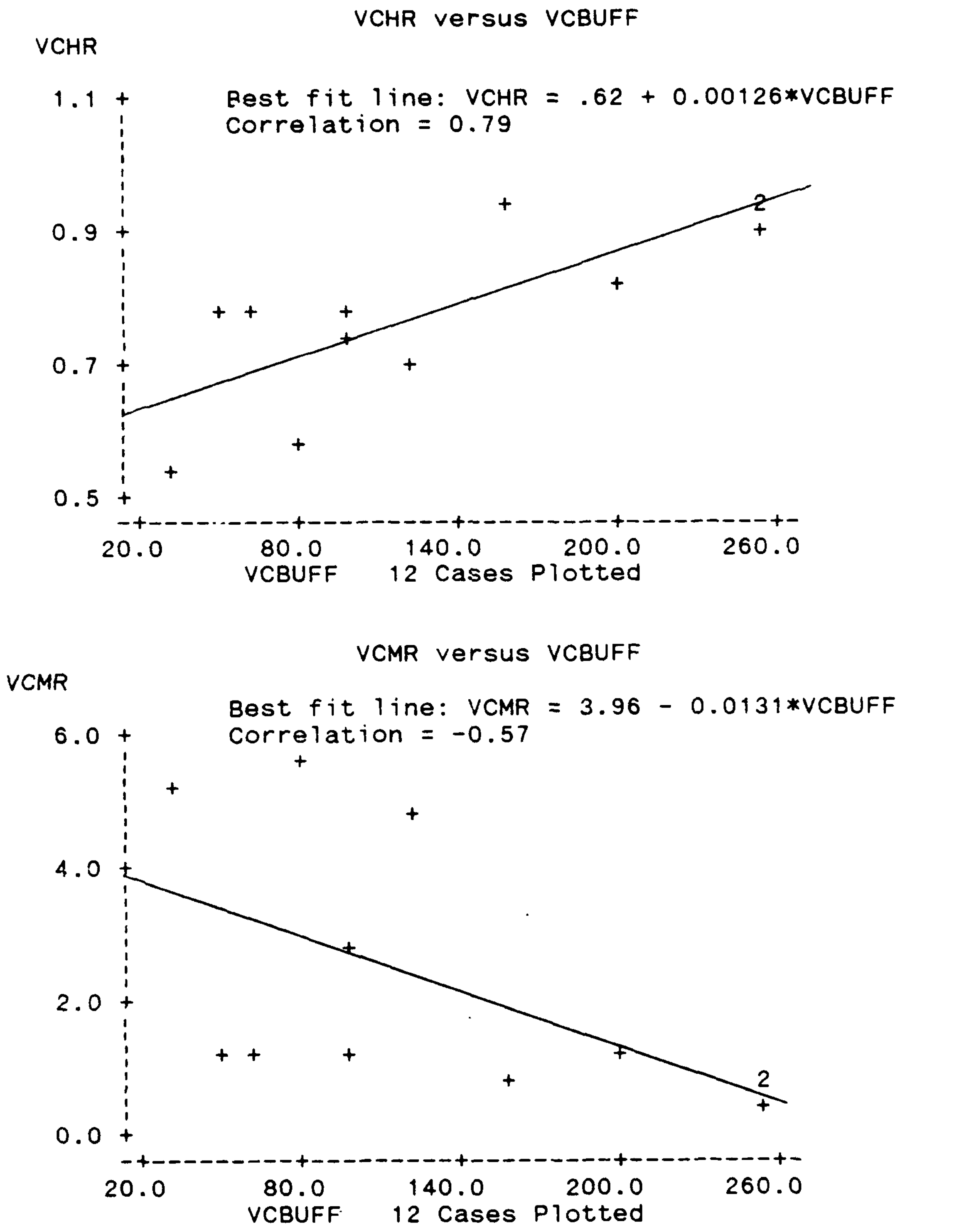



Figure 4-2. Miss Rate and Hit Ratio Versus Buffers

small compared to other effects. Another possibility is that system performance and cache size are related but not in a linear fashion. Figure 4-1 shows a plot of MPI and SPI versus the VTOC cache size. A relation as depicted by the sketched line may exist. It seems unlikely that such a great impact on overall performance could be caused by moderate changes in the VTOC cache size. VTOC cache size may be correlated with other variables that explain the relation to performance. Or the results may be simply a result of random chance. Further testing is necessary to validate these findings.

Figure 4-2 contains plots of the VTOC hit ratio and the miss rate versus the cache size. The hit ratio is clearly an increasing function of cache size. This fits literature predictions. The miss rate is not so clearly a function of the size. Still, the trend is for a decreasing miss rate with increasing cache size which also fits predictions. Linear regression of these variable provides a best fit line function. These equations are displayed in the figure. The equations provide a means to estimate the cache size needed to achieve a desired hit ratio or miss rate.

With this model, an optimum operating point can be determined. Wang's recommended hit ratio is 0.9. Others consider this too high. Using 0.8, the number of buffers needed by the model equation is 142. One rule of thumb for the miss rate is to keep it below 4 misses per second.

Using 3 as a target, the number of buffers required is 73. Perhaps 100 buffers would be a good initial setting. If the system has a large amount of memory, up to 175 buffers might be prudent.

Other analyses show a strong linear correlation between system performance and miss rate and hit ratio. This is not considered a useful correlation. A prime determinant of system performance is workload. A system with low workload will show good system performance. Smaller workloads will result in higher hit ratios and lower miss rates regardless of the cache size.

Sharer Analysis. Table 4-8 displays descriptive statistics for Sharer buffers and a histogram showing the distribution of the buffer quantity. A wide range of Sharer sizes are in use with no particular preferences for small or large sizes. Variables associated with the Sharer are examined to further determine their possible affect on performance.

Linear regression and scatter plots fail to reveal any significant relation between system performance and the number of Sharer buffers. Tables 4-9 and 4-10 show the results of ANOVA concerning the fixed/not fixed setting of the Sharer control blocks and buffers. Mean performance indices are higher for non-fixed control blocks, but the large P values indicate little statistical assurance of this relation. Conversely, there is strong evidence system

Table 4-8. Sharer Statistics

Descriptive Statistics of SBUFF

| Description | Var | Mean | SD | N | Min | Max |
|---|---|---|---|---|---|---|
| Number of SHARER buffers | SBUFF | 249.6 | 138.8 | 22 | 40 | 510 |

Histogram of SBUFF

| Low | High | N | |
|---|---|---|---|
| 30 | 100 | 2 | ¦************ |
| 100 | 170 | 6 | ¦************************************ |
| 170 | 240 | 3 | ¦****************** |
| 240 | 310 | 4 | ¦************************ |
| 310 | 380 | 1 | ¦****** |
| 380 | 450 | 4 | ¦************************ |
| 450 | 520 | 2 | ¦************ |

performance indices are higher for systems with non-fixed buffers. These same results are obtained using a t-test.

A correlation of the number of Sharer buffers against the miss rate and hit ratio was planned but could not be conducted. Data from the bases were not properly obtained in several cases. This problem occurred because some SAs did not reset the Sharer counters at the beginning of the test period. In some cases the result is a miss rate much higher than considered possible and is therefore obvious. However, in other cases, the same mistake may be masked by coincidental reasonable results. Since several respondents clearly made the error, many others may have also. As a result, the reliability of the data is suspect. Data for

Table 4-9. ANOVA for Performance = Sharer Control Block Setting

One Way AOV for MPI = SCBF

| SCBF | Mean | Sample Size | Group Variance |
|---|---|---|---|
| 0 | 3.362 | 14 | 4.255E-01 |
| 1 | 3.319 | 8 | 3.947E-01 |
| Total | 3.346 | 22 | |

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Between | 1 | 9.304E-03 | 9.340E-03 | 0.02 | 0.8222 |
| Within | 20 | 8.294 | 4.147E-01 | | |
| Total | 21 | 8.303 | | | |

One way AOV for SPI = SCBF

| SCBF | Mean | Sample Size | Group Variance |
|---|---|---|---|
| 0 | 117.2 | 14 | 1.663E+03 |
| 1 | 124.2 | 8 | 1.302E+03 |
| Total | 119.7 | 22 | |

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Between | 1 | 253.4 | 253.4 | 0.16 | 0.6890 |
| Within | 20 | 3.074E+04 | 1.537E+03 | | |
| Total | 21 | 3.099E+04 | | | |

Table 4-10. ANOVA for Performance = Sharer Buffers Setting

One way AOV for MPI = SBUFFF

| SBUFFF | Mean | Sample Size | Group Variance |
|---|---|---|---|
| 0 | 3.614 | 10 | 4.390E-01 |
| 1 | 3.123 | 12 | 2.762E-01 |
| TOTAL | 3.346 | 22 | |

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Between | 1 | 1.314 | 1.314 | 3.76 | 0.0667 |
| Within | 20 | 6.989 | 3.495E-01 | | |
| Total | 21 | 8.303 | | | |

One way AOV for SPI = SBUFFF

| SBUFFF | Mean | Sample Size | Group Variance |
|---|---|---|---|
| 0 | 107.6 | 10 | 1.719E+03 |
| 1 | 129.8 | 12 | 1.168E+03 |
| Total | 119.7 | 22 | |

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Between | 1 | 2.672E+03 | 2.672E+03 | 1.89 | 0.1847 |
| Within | 20 | 2.832E+04 | 1.416E+03 | | |
| Total | 21 | 3.099E+04 | | | |

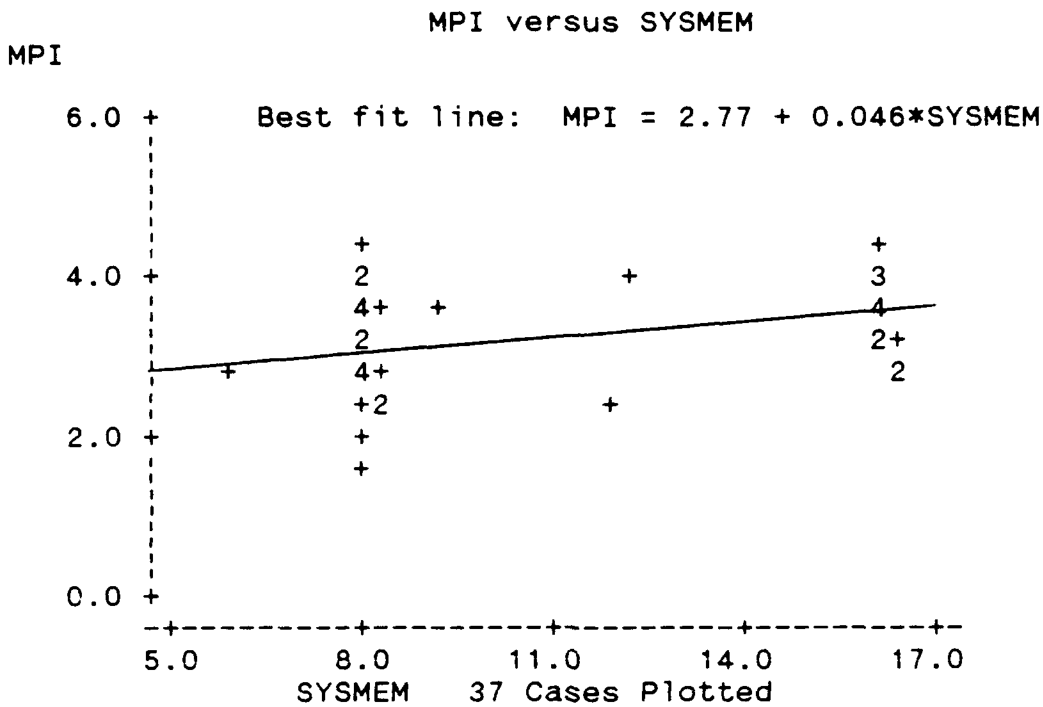
the number of buffers and fix/not fixed settings are still considered accurate.

System Memory. The sample average memory installed is 11 MB. The high is 16 and the low is 6 MB.

Linear regression and scatter plots show a distinctive linear relation between system performance and the amount of system memory. More memory is related to better performance. The plots of system performance variables versus memory size are in figure 4-3. The model equations for the best fit line are included. Table 4-11 provides the results of linear regression for system performance. These results are in line with literature predictions. Note the large variance of system performance around the linear regression line. While increasing memory may improve performance in general, performance may still vary widely for a given memory size.

Users. The number of users assigned to the computer shows the strongest affect on system performance of all interval level variables tested. A plot of system performance versus the number of users is at figure 4-4. Linear regression results are at table 4-12. The small P value of 0.02 means the statistical significance is very certain.

Administrative Tasks. Administrative tasks are heavy resource demand programs that do not have to be done during peak demand periods. Analysis showed a possible relation



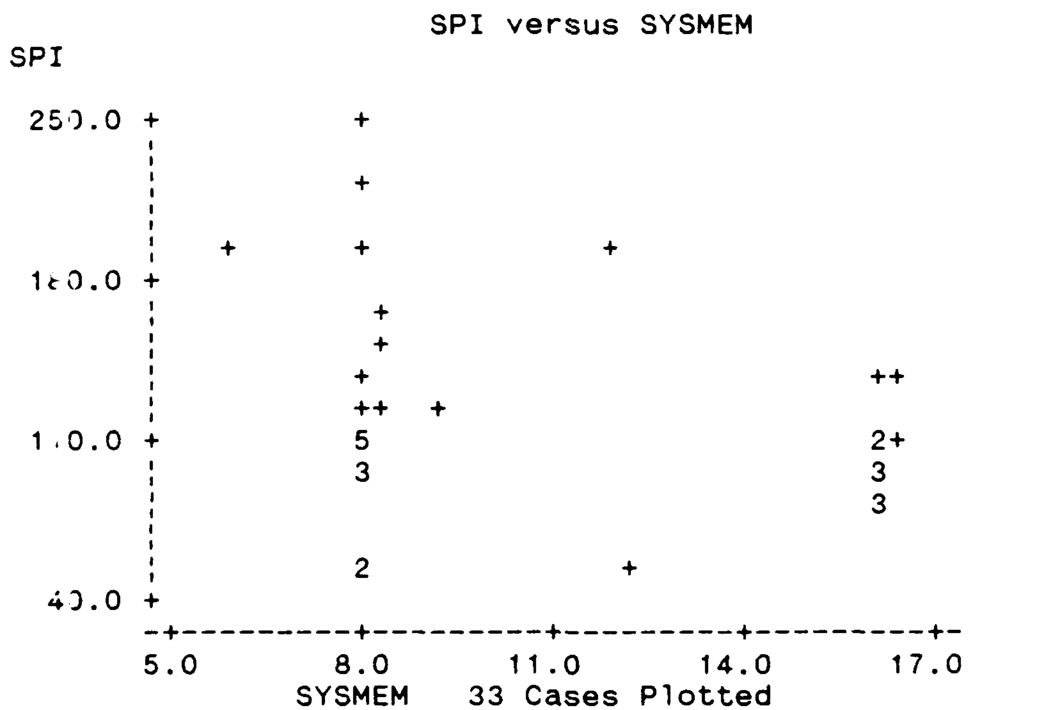




Figure 4-3. System Performance Versus Memory Size

Table 4-11. Regression of Performance = Memory Size

Unweighted Least Squares Linear Regression of MPI

| Predictor Variables | Coefficient | Std Error | P |
|---|---|---|---|
| Constant | 2.7743 | 3.2832E-01 | 0.0000 |
| SYSMEM | 4.5542E-02 | 2.8032E-02 | 0.1132 |

| | | | |
|---|---|---|---|
| Cases Included | 37 | Missing Cases | 4 |
| Degrees of Freedom | 35 | | |
| Overall F | 2.639 | P Value | 0.1132 |
| Adjusted R Squared | 0.0436 | | |
| R Squared | 0.0701 | | |
| Resid. Mean Square | 4.272E-01 | | |

Table 4-12. Regression of Performance = Number of Users

Unweighted Least Squares Linear Regression of MPI

| Predictor Variables | Coefficient | Std Error | P |
|---|---|---|---|
| Constant | 4.2813 | 4.2562E-01 | 0.0000 |
| USERS | -3.5870E-03 | 1.4746E-03 | 0.0203 |

| | | | |
|---|---|---|---|
| Cases Included | 37 | Missing Cases | 4 |
| Degrees of Freedom | 35 | | |
| Overall F | 5.917 | P Value | 0.0203 |
| Adjusted R Squared | 0.1202 | | |
| R Squared | 0.1446 | | |
| Resid. Mean Square | 4.019E-01 | | |

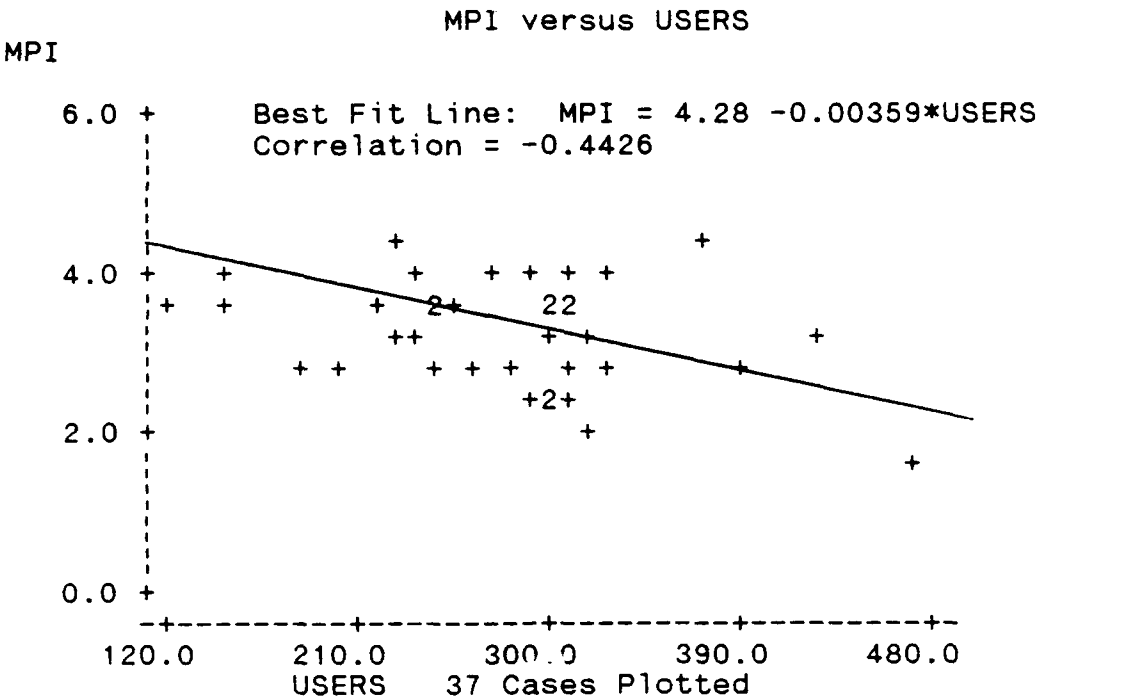



Figure 4-4. System Performance Versus Number of Users

between the amount of administrative tasks done during duty hours and system performance. A plot of system performance variables versus the measure of the work during duty hours is at figure 4-5. The regression results are at table 4-13. The P value of .19 means there is approximately a 20 percent chance that the coefficient is a result of random chance due to variation in the data. We cannot be very confident this relation is statistically significant.

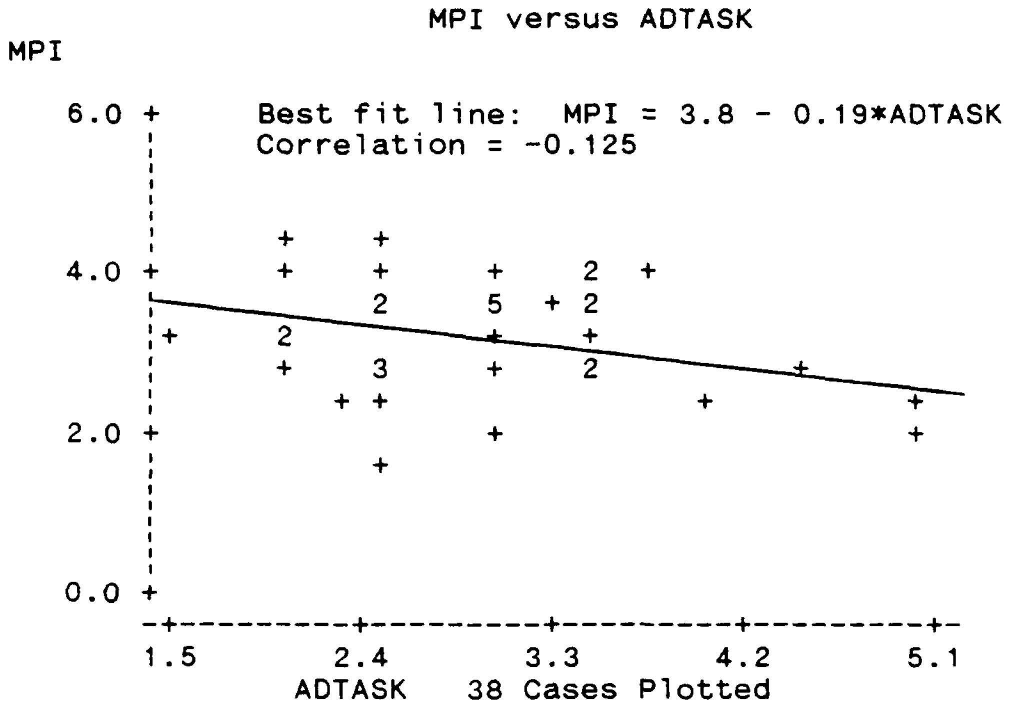
Differences for MAJCOMS. MAJCOMs' support to base SAs could have a significant impact on system performance. Some major commands may put more emphasis on performance. Differences in base system performance levels by MAJCOM is sought. Analysis of Variance is used to see if differences in MPI and SPI are significant. Table 4-14 contains the

Table 4-13. Regression of Performance = Administrative Tasks

Unweighted Least Squares Linear Regression of MPI

| Predictor Variables | Coefficient | Std Error | P |
|---|---|---|---|
| Constant | 3.8036 | 4.3408E-01 | 0.0000 |
| ADTASK | -1.8738E-01 | 1.4069E-01 | 0.1913 |

| | | | |
|---|---|---|---|
| Cases Included | 38 | Missing Cases | 3 |
| Degrees of Freedom | 36 | | |
| Overall F | 1.774 | P Value | 0.1913 |
| Adjusted R Squared | 0.0205 | | |
| R Squared | 0.0470 | | |
| Resid. Mean Square | 4.678E-01 | | |



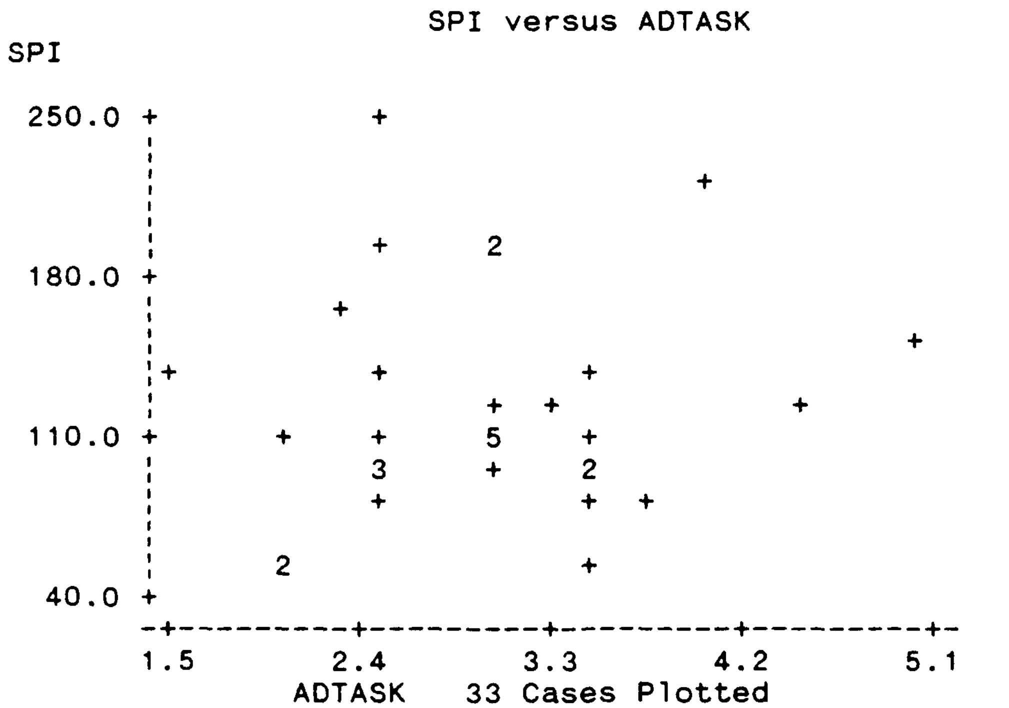




Figure 4-5. System Performance Versus Administrative Tasks

Table 4-14. ANOVA for Performance = MAJCOM

One way AOV for MPI = MAJCOM

| MAJCOM | Mean | Sample Size | Group Variance |
|---|---|---|---|
| 1 | 3.508 | 9 | 3.416E-01 |
| 2 | 2.973 | 5 | 1.297 |
| 3 | 3.343 | 11 | 3.610E-01 |
| 4 | 3.014 | 6 | 4.998E-01 |
| 5 | 3.435 | 1 | M |
| 6 | 3.591 | 1 | M |
| 7 | 3.019 | 3 | 2.479E-01 |
| 8 | 3.571 | 1 | M |
| TOTAL | 3.269 | 37 | |

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Between | 7 | 1.814 | 2.592E-01 | 0.52 | 0.8139 |
| Within | 29 | 14.53 | 5.009E-01 | | |
| TOTAL | 36 | 16.34 | | | |

One way AOV for SPI = MAJCOM

| MAJCOM | Mean | Sample Size | Group Variance |
|---|---|---|---|
| 1 | 114.1 | 8 | 1,140 |
| 2 | 152.6 | 5 | 6,616 |
| 3 | 116.0 | 9 | 2,022 |
| 4 | 101.5 | 4 | 1,111 |
| 5 | 92.80 | 1 | M |
| 6 | 103.0 | 1 | M |
| 7 | 133.9 | 3 | 643.9 |
| 8 | 115.4 | 2 | 176.7 |
| TOTAL | 119.8 | 33 | |

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Between | 7 | 8.744E+03 | 1.249E+03 | 0.56 | 0.7781 |
| Within | 25 | 5.542E+04 | 2.217E+03 | | |
| TOTAL | 32 | 6.416E+04 | | | |

M = missing

results of this testing. P values of 0.78 and 0.81 signify no significant differences by MAJCOMs.

FASTLINK. Information on FASTLINK file usage is obtained from eight bases on 26 different programs. Table 4-15 lists the data collected. Programs that are good candidates for FASTLINK are short lived and have high usage. This means the mean active users should be less than 1 (smaller is better) and the mean usage should be "large". Based on this criteria, the files that would be good candidates are marked.

Sixty-four percent of the base respondents use FASTLINK (N=14). The mean number of files in FASTLINK is 7.4. The low is 4 and high is 16. Several base SAs indicate little performance improvement with FASTLINK. One base eliminated the program from their system. No significant relation between use of FASTLINK and system performance is found.

Caution should be exercised when using the data for FASTLINK. The extremely small sample sizes result in great risk that the statistics provided are far from true representations.

I/O Bottleneck Detection. The program at appendix G provides data on I/O bottleneck times. These times are compared against other factors. MPI and the mean of all I/O bottleneck times for a base have a negative correlation of -0.51. This is consistent with what is expected if both are valid measures. A plot of MPI versus time is at figure 4-6.

Table 4-15. FASTLINK Candidates

| File Name | | Variables | Mean Users | Mean Usage | N |
|---|---|---|---|---|---|
| INQUIRY | | F1xxxx | 0 | 0.2 | 3 |
| SORT | * | F2xxxx | 0 | 11.4 | 5 |
| DISPLAY | * | F3xxxx | 0.17 | 6.7 | 5 |
| REPORT | * | F4xxxx | 0.45 | 5.2 | 5 |
| COPY | * | F5xxxx | 0 | 5.6 | 2 |
| IVARUREAD | | F6xxxx | 0 | 1.4 | 1 |
| IVARVALS | * | F7xxxx | 0.12 | 4.3 | 3 |
| WG3PRINT | * | F8xxxx | 0.17 | 3.9 | 3 |
| @SHARER@ | | F9xxxx | 1 | 0 | 1 |
| @OPER@ | | F10xxxx | 1 | NR | 1 |
| WSRSTR | | F11xxxx | 0 | NR | 1 |
| @ATTACH@ | | F12xxxx | 1 | NR | 1 |
| @PROC@ | | F13xxxx | 23.5 | NR | 1 |
| @SYSINIT | | F14xxxx | 65.5 | NR | 1 |
| IVAR4PRT | | F15xxxx | 0.5 | 0.1 | 1 |
| MWDAUD | | F16xxxx | 3 | 6.5 | 1 |
| WG3CANDM | | F17xxxx | 0 | 0.5 | 1 |
| MBMIUD | * | F18xxxx | 0.5 | 5.5 | 1 |
| WPEMUSSL | * | F19xxxx | 0 | 49 | 1 |
| MJOBUD | | F20xxxx | 3 | 9 | 1 |
| WC1PASS1 | | F21xxxx | 0 | 3.6 | 1 |
| WC1PASS2 | * | F22xxxx | 0 | 5 | 1 |
| COBOL | * | F23xxxx | 0 | 5 | 1 |
| EDITOR | | F24xxxx | 0.5 | 1.5 | 1 |
| WPDISP | ** | F25xxxx | 0 | 0 | 1 |
| COPYWP | | F26xxxx | 0 | 1.4 | 1 |
| @OPER@ | | F27xxxx | 2 | 7 | 1 |

NR = not reported
* - evidence of being well suited for FASTLINK
** - reported to be a good candidate but not backed by data

The small sample size and the presence of an outlier make it difficult to state confidence in this relationship. A nonparametric ANOVA confirms a very significant difference between disks with crash and no protection levels. Crash protection is related to greater I/O times. A nonparametric measure is used because the bottleneck times are not normally distributed. Table 4-16 contains the ANOVA results. Numerous other relations are sought for the bottleneck times but none are statistically significant.

```
                      MPI versus MDIOBNT
MPI

   3.9 +
       |         +
       |              +
       |                +  +  +
       |         +
   3.3 +           +
       |
       |
       |
       |                           +
   2.7 +
       |
       |
       |
       |
   2.1 +                    +
       -+---------+---------+---------+---------+-
       0.00      0.2       0.4       0.6       0.8
                MDIOBNT    9 Cases Plotted
```

Figure 4-6. System Performance Versus I/O Bottleneck Times

Table 4-16. ANOVA for I/O Times = Fault Tolerance Setting

Kruskal-Wallis Oneway Nonparametric AOV for IOBNT = FTS

| FTS | Mean Rank | Sample Size |
|---|---|---|
| 1 | 19.9 | 36 |
| 2 | 38.2 | 12 |
| Total | 24.5 | 48 |

| | |
|---|---|
| Kruskal-Wallis Statistic | 15.3503 |
| P Value, Using Chi-Squared Approximation | 0.0001 |

Parametric AOV Applied to Ranks

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Between | 1 | 3.007E+03 | 3.007E+03 | 22.31 | 0.0000 |
| Within | 46 | 6.199E+03 | 134.8 | | |
| Total | 47 | 9.206E+03 | | | |

CASES INCLUDED 48 MISSING CASES 297

All bases were included in this test. Cases refer to the number of disk drives sampled.

Other Variables. Other variables tested against system performance are disk drives, SA manning, total work stations, SA experience, SA training, use of performance analysis and tuning tools, and collocation of files on disk. None show a significant relation to performance.

This should not imply that SA manning, experience, or training are unimportant. SAs have many responsibilities other than monitoring performance. Many of these other tasks must be given higher priority. The data likely reflect these priorities.

Page Pools. Five of twenty respondents or twenty-five percent have paging files on their disks. Two do not have page pools on their system volumes. Additionally, one of these has another page pool over committed. Two have system page pools, but they are over committed. One case is unexplained. Paging to files can reduce system performance. The problem is easy to fix unless disk space is very limited. Twenty-five percent seems excessive.

File Packing Factors and Compression. All respondents reported a 100% packing factor for their data files. Therefore, comparisons for different packing factors is not possible. Approximately 85 percent of the files examined are compressed. No relations are found between file compression and system performance, I/O bottleneck times, or file fragmentation.

Multiple Linear Regression. Multiple linear regression is attempted for several predictor performance variables. Results conflict with the simple linear regression and give coefficients deviating from assumed expectations. Because many of the variables have high intercorrelations and the sample size is low, multicollinearity problems are suspected.

## Question 8

Information is examined for five performance analysis and tuning software packages. The five packages are System Minder, Space Saver, WORM, SAM, and VS Space. Each package

is evaluated for its ability to improve system performance and overall value to the SA. Table 4-17 contains the results of analysis on this data. Higher numbers represent greater perceived improvement in performance or greater overall value to the SA. The sample sizes are quite small and confidence intervals are not calculated. Both SAM and WORM score below 3 which represents "a little" perceived

Table 4-17. Performance Software Ratings

Statistics for the Improvement in Performance

| Package | Var | Mean | SD | N | Min/Max |
|---|---|---|---|---|---|
| System Minder | SP1IP | 3.33 | 0.52 | 6 | 3/4 |
| Space Saver | SP2IP | 3.67 | 0.58 | 3 | 3/4 |
| WORM | SP3IP | 2.8 | 0.45 | 5 | 2/3 |
| SAM | SP4IP | 2.3 | 1.16 | 3 | 1/3 |
| VS Space | SP5IP | 4.0 | 0 | 3 | 4/4 |

Statistics for Overall Value

| Package | Var | Mean | SD | N | Min/Max |
|---|---|---|---|---|---|
| System Minder | SP1V | 4.67 | 0.52 | 6 | 4/5 |
| Space Saver | SP2V | 4.33 | 0.58 | 3 | 4/5 |
| WORM | SP3V | 3.8 | 0.45 | 5 | 3/4 |
| SAM | SP4V | 2.67 | 1.53 | 3 | 1/4 |
| VS Space | SP5V | 4.33 | 0.58 | 3 | 4/5 |

improvement in performance accountable to the product. VS Space has the highest overall score with all three respondents rating it a 4. SAM and WORM may have received poorer scores, because they are analysis packages. In contrast, the other three packages perform system tuning that can result in improved performance. The results are similar for overall value. System Minder is rated slightly higher and SAM again scores the lowest. It is worth pointing out that SAM has a large variance in both measures. This means there are large differences in attitudes concerning this product. This may be because the program requires considerable expertise to properly use. Thus, a knowledgeable SA might like the product, while another, less knowledgeable SA, might find it of little value. No relation is found between system performance and use of a performance tuning or analysis package.

### Cautionary Remarks

Numerous important statistical relations are presented in this chapter. The reader is cautioned about interpretation of the results. The relations found do not prove causation. For example, one can say that systems with higher performance indices are associated with greater memory, but this does not prove that greater memory causes better performance. Controlled experiments are required to firmly establish the causal factors.

# V. Summary and Recommendations

## Introduction

This research examined system performance for WIMS. In general, systems are operating at satisfactory levels, and users are not unhappy with performance. However, some bases do have performance problems.

SAs are knowledgeable in most areas of system performance and do perform performance analysis and tuning work on their systems.

Greater system memory, fewer users, and less administrative tasks during duty hours are found to be related to better performance. Larger VTOC caches seems to help to a point. Unfixed Sharer buffers are related to superior performance. Sharer buffer size does not seem to affect performance. No disk fault tolerance results in longer I/O times and should therefore improve performance.

Initial performance measurements are available for later comparisons. Two new performance measurement tools are tested. A survey tool and tutorial are created.

Recommended system settings, economic analysis, and ideas for future research are now presented.

## Recommended Settings

The inexperienced SA needs to have comprehensive guidance for system parameter settings. This is especially true for new systems when no one with previous experience is

Table 5-1. Recommended Parameter Settings

VTOC Cache Size. 100 buffers if main memory is less than 8 MB. 175 buffers if main memory is between 8 and 16 MB

SHARER Buffers Size. 150 buffers if main memory is less than 4 MB. Otherwise maximize at a setting of 255 buffers in the configuration file (resulting in 510 buffers created).

SHARER Buffers Configuration. SHARER buffers should be unfixed and SHARER control blocks may be fixed or not fixed.

Disk Fault Tolerance Setting. Crash or None. System disk should always be crash. Disks with no protection should be backed up daily.

FASTLINK files. Run the following files under FASTLINK: WPEMUSSL, SORT, DISPLAY, REPORT, COPY, MBMIUD, and WC1PASS2.

Page Pools. At least 4 disks enabled for paging. All disks enabled is preferred. System disk must have a page pool.

System Memory. As much as can be afforded.

available. Table 5-1 contains a list of recommended settings for a WIMS. The list is derived from the research and from other sources. It represents the best opinion of the author. This list is intended as a starting point for system configuration and parameter settings when no better recommendations exist. Undoubtedly, better combinations exist for specific systems. Further research may uncover flaws in these recommendations or at least improve upon them. Still, the recommendations in this list would be much better than random guessing. It is recommended that this or a similar list be furnished to SAs when they configure their systems. Poorly performing systems may benefit by converting to these settings.

Economic Analysis. The results of this research can be used to estimate the value of particular performance tuning action. This is illustrated in three cases. First, a relation is hypothesized for the expected change in average user waiting time based on a change in MPI. One hundred seconds saved for each unit increase in MPI is hypothesized. The mean value of MPI is assumed to correspond to the mean value of MWAIT, 3.26 and 457 seconds respectively. This estimation results in a change in lost time by a factor of 2.6 over the entire range of MPI. SPI varied by a factor of 5 from the worst to the best in the sample. SPI is assumed proportional to other delays occurring in the system. Therefore, the proposed relation of MPI and WAIT seems reasonable and conservative based on the above comparisons, personal experience, and the variance in the actual data for WAITx. Note this relation is hypothesized and not specifically determined from the data. The resulting model equation is

$$WAIT = 780 - 100*MPI \tag{2}$$

where

WAIT is the average waiting time per user (seconds)

MPI is the master performance index

System Memory. Previous analysis provides a relation between memory and the performance index.

$$MPI = 2.77 + 0.046*SYSMEM \tag{3}$$

where

SYSMEM = the amount of system memory (megabytes)

Substituting 3 into 2 yields

$$\text{WAIT} = 503 - 4.6*\text{SYSMEM} \tag{4}$$

This relation can be used to estimate the value of a memory increase. Consider a case where an upgrade from 4 to 16 megabytes is contemplated. Analysis is for an average WIMS installation. From equation 4, the resulting reduction in lost time from this change would be 55 seconds. For 278 users, this results in an annual savings of approximately $19,000 at $15 per hour. The cost of 12 MB of memory is approximately $12,000, and so the cost would be paid back in less than one year.

<u>Sharer Buffers</u>. One significant finding is that systems with unfixed Sharer buffers have higher performance indices on the average than those with fixed buffers. The difference in the means of MPI between these two groups is 0.48. This represents the expected amount of increase in MPI when going from fixed to unfixed buffers. The expected change in WAIT using equation 2 is -44 seconds per user. The sample data suggest that approximately 50 percent of the WIMS have fixed buffers. There are 130 systems currently in operation so 65 could switch. Using identical assumptions about the number of users and work days, one can calculate

an estimate of 1000 hours saved per base per year or $975,000 per year for the AF. Changing the buffer setting requires only a few minutes of an SA's time and can easily be changed back if desired.

Users. A similar analysis can be done for users showing that, based on time savings alone, purchasing a second computer to reduce the number of users on one would rarely be economically attractive.

## Further Research

Considerable opportunity exists for further research in the area of WIMS system performance. As CE becomes more dependent on its computer resources, the issue of system performance will become more important. The following areas should be considered.

Further Data Analysis. Additional analysis opportunities are available with the existing data set. Multiple regression could incorporate several variables in a model for performance.

Performance Index Generator. A basic assumption of this research is that the performance index generator provides an accurate representation of performance. Research should be conducted to validate this assumption. This could be done by comparing the results of this generator with one of more complexity and known accuracy. WIMS SAs would benefit from a proven performance index generator.

I/O Bottleneck Detector. The results of this research did not confirm the validity of the I/O bottleneck detection program. If it is a valid measurement, the program could be confidently used by SAs. Validation could be made by comparing the results of the program with a more sophisticated analysis tool that measures I/O queues.

Analysis and Tuning Software. More information is needed to evaluate the value of these packages. Understanding and using a powerful system analysis package such as SAM may be the key to making significant gains in system performance.

FASTLINK. The list of candidate files for FASTLINK could be greatly improved by some rather simple research in this area. One would have to identify programs run on a WIMS, put them under FASTLINK, and monitor them for a duration of several weeks. The results would be beneficial.

Packing Factors. Little was learned about the value of packing factors less than 100%. Research could be done specifically in this area.

New Areas. Areas not included in this research could be explored.

Hardware Configuration. Hardware configuration is said to be a determinant of system performance. This is only partially explored in this research.

File collocation. A list of candidate files for collocation should be developed. Clearly, many SAs have

gone through the exercise of collocating files, but a recommended list of files to collocate apparently does not exist. The knowledge is available and needs documentation.

Different Hardware. Hardware speed continually improves. A vast array of options exist to build faster systems. New CPs, faster disk drives, and smarter work stations could all help. Research could focus on what is available and on the best options for upgrading our present systems.

Software Efficiency. A large area for possible investigation is the efficiency of software running on WIMS. Of special interest is the software written by the USAF such as WIMS, CEMAS, and PDC. Different programming strategies could be experimented with to determine the fastest.

Controlled Experimentation. This research did find some important relations between variables, but in general, the relationships are weak. System performance is a function of so many variables that it is difficult to glean out the relationships between system performance and each variable using the techniques of this research. Controlled experimentation should solve both problems. By changing one variable of a system and monitoring the results over an extended period, relationships would be more clearly defined.

## Appendix A: Definitions, Acronyms, and Abbreviations

AFB - Air Force Base.

AFLC - Air Force Logistics Command.

AFSC - Air Force Systems Command.

ANOVA - Analysis of Variance.

ATC - Air Training Command.

AU - Air University.

BEAMS - Base Engineer Automated Management System.

BCAS - Base Contracting Acquisition System. A Wang VS based computer system for base contracting.

BCE - Base Civil Engineer.

block - "a number of physical records, each 2048 (2K) [2 kB] in length, which make up a disk volume" (23:Glossary.1)

bottleneck - a condition where demands on a certain resource of a system are overloaded and are slowing the overall computing process.

buffer - a 2 kB area in memory that temporarily holds information.

buffer pool - a group of buffers.

CE - Civil Engineering.

CEMAS - Civil Engineering Material Acquisition System

commitment ratio - the sum of the modifiable data areas of all current users of a page pool. The CR applies to all active page pools in the system. (26:2.8)

CP - central processor. Alternately called CPU for "central processing unit".

CR - commitment ratio.

data - used in this document to mean information processed by programs such as database files or text in word processing documents.

disk I/O - I/O involving disk drives. Includes paging I/O, data I/O, or VTOC I/O.

extent - a group of contiguous blocks on a disk (23:G.3).

fragmentation - a condition where the data associated with individual files is split up on a disk. (26:4.1)

free extents - a group of contiguous blocks on a disk volume that is not assigned to a file. (23:Glossary.3)

hardware configuration - the number and type of hardware components and how they are connected together.

hit - when the system finds information it needs in main memory. (26:2.14) See miss.

I/O - input/output.

information - data or program code.

input/output - the transfer of data between physical memory and a peripheral device. Abbreviated "I/O". (26:2.5)

interactive processing - processing that require periodic input from and gives periodic output to a work station (23:1.1).

IOP - input/output processor. The interface device between physical memory and all peripheral devices. Similar to an IOC (input/output controller). (26:2.5)

IPL - initial program load.

kB - kilobytes

kilobytes - 1024 bytes. Abbreviated "kB".

MAC - Military Airlift Command.

MB - megabytes

MDA - modifiable data area. A segment of virtual memory, assigned to a running applications that holds modifiable program code such numbers assigned to variables. Formerly called "Segment 2". (26:2.8)

megabyte - one thousand kilobytes or 1,024,000 bytes. Abbreviated "MB".

miss - an event - when the system cannot find information it needs in main memory.

modifiable data area - see "MDA".

non-interactive processing - processing where no inputs from the workstation are required and where no outputs to the workstation occur (23:1.1). Also known as background processing.

non-shared data - Data that can be accessed or modified by only one task. Non-shared data come from non-shared files. (26:2.12) See also "shared data".

object code - program files containing instructions written in machine language.

PACAF - Pacific Air Forces.

page - "a 2 kB division of virtual memory that contains part of a user's memory image. (26:2.4)"

page frame - "a 2 kB piece of physical memory into which the system can place a page. (26:2.4)"

page pool - an area on disk, set up by the system administrator, to hold data that has been paged out to disk. Each volume may have its own page pool. Each user is assigned to a specific page pool. (26:2.7) See also paging file.

paging - the process of transferring data between disk and physical memory when a program calls for a virtual address which is not currently in physical memory. (26:2.4)

paging area - a page pool or paging file. (26:2.7)

paging file - a file created on disk, set up automatically by the system, to hold data paged out to disk. Only used when page pools are full or don't exist. (26:2.7)

paging I/O - the total of all of all page-ins and page-outs. (26:2.7)

parameter - a variable of a computer system that can be set by the system administrator.

performance - the rate at which a computer system does work.

performance analysis - identifying bottlenecks that are causing poor performance.

performance index - A number that describes the performance of a system.

performance tuning - modifying system configuration or parameter settings to improve performance.

peripheral device - a device connected to the main computer -usually considered terminals, printers, disk drives, or communication systems.

physical memory - actual memory installed in the system. Also called main memory.

population - data about all individuals or objects of a particular type (17).

precision - a measure of how close several measurements will be to another, sampling error. (4:277)

queue - a waiting line.

record - the smallest unit of data that is processed together.

response time - "the time delay between pressing the ENTER key (or equivalent) and the full display of the response screen, which allows the operator to continue." (26:1.2)

SA - System Administrator. Also referred to as the "SSA" or the "System Operator".

SAC - Strategic Air Command.

sampling design - the plan of collecting data from a subset of the population of interest. (4:278-283)

seek - "the action of moving the disk arm. (26:2.6)"

shared data - data from a share file.

shared file - "a file [of data] that can be accessed and updated by multiple tasks. (26:2.12)" See also non-shared data.

SHARER - a program that controls access to data files so that more than one task may access the file at one time. (26:2.12)

SHARER buffers - buffers set up for shared data files. (26:2.13)

SHARER control blocks - blocks of virtual memory containing control information for the Sharer. (26:2.15)

source files - program files containing instructions written in a programming language (typically COBOL for WIMS).

TAC - Tactical Air Command.

transfer rate - the speed of transferring data through a communication channel, expressed as bytes per second. (26:2.7)

turnaround time - "the time required to complete long-running programs such as batch jobs. (26:1.3)"

USAF - United States Air Force.

USAFE - United States Air Forces in Europe.

volume - "an independent storage device" such as a disk drive or tape. (23:Glossary.8). Volume is often used synonymously with disk drive but this use will be avoided.

VS - virtual system. A computer that uses virtual memory.

VTOC - Volume table of contents. "a directory of files, libraries, and free space on a volume. (26:2-19)"

WIMS - Work Information Management System. A minicomputer system used by USAF Civil Engineering. This includes the Wang VS hardware, AFESC developed, CEMAS, Wang, and other software, and data. (Actual use of this term is mixed. To some is refers only to the AFESC developed software, but more commonly, it is used to refer to the entire CE Wang VS computer system.)

work files - temporary files created by the operating system (23:1.16)

## Appendix B: Standard Performance Analysis and Tuning Tools

The following is a summary of performance analysis and tuning functions and programs that are standard on a normal WIMS. Where a utility or program has subfunctions, they are listed in a hierarchial manner.

A - <u>The Wang VS Command Processor</u>.

A1 - Manage Files/Libraries. [PF5]. Provides information on the number and names of libraries on a volume and the number and names of files in each library.

A1A - Display Free Extents. [PF12]. Displays information on the number and size of free extents on each volume.

A2 - Show Program Completion Report. [PF3]. Provides resource demand information of a program (executed from the Command Processor) that has just finished running. Can help to assess how efficiently a program is using system resources. Specifically shows total elapsed time, program processing (CP) time, workstation I/O operations, printer I/O operations, tape I/O operations, non-paging disk I/O, page-ins, page-outs (system and program paging) and modifiable data area size for the current user and remaining MDA space.

A3 - Show Program Status. [PF3]. Provides all the information of tool A2 in addition to the number of bytes remaining in a task's MDA. This function is only active after interrupting a program during execution.

A3A - Show Files and Devices in Use. [PF1]. Provides information about all of the files and devices the interrupted program is using.

A3B - Show Buffer Pooling Statistics. [PF2]. Provides information on existing buffer pools including number in use and for each individual buffer, the files using the buffer, buffer size, hit count, and miss count.

A4 - Manage Devices. [PF6].

A4A - Disks. [PF3]. Provides information identically the same as tool B3.

B - <u>Operator Console</u>. [PF11 from the Command Processor Screen]. Error messages are generated at the operators console. Two related to system performance are page pool and GETMEM warning messages.

B1 - Control Interactive Tasks. [PF6]. Provides a listing of currently running interactive programs by user, how long each has been

running, and the total CPU time consumed by each. Also which user is on what workstation.

B1B - Paging and I/O. [PF7]. Provides the following information on all active interactive tasks by user: workstation I/O, disk I/O, tape I/O, print I/O, other (telecommunications ) I/O, page ins and page outs (for the program and the system).

B1C - Program Status. [PF8]. Provides information on the usage of files by a particular active user (workstation). Includes where the file resides, the mode of the file, the total of I/O transfers, file name, library, volume, and extents.

B2 - Non-interactive Tasks. [PF7]. Provides identical information as for the interactive tasks as in tool B1.

B2A - Initiator Control/Create New Initiator [PF11,PF7]. Provides the default MDA.

B3 - Manage Disks. [PF10]. Provides information on disk fault tolerance settings for each disk.

B3A - Owner Information. [PF11]. Provides information on and control of disk that are enabled for paging, work files, and spooling (printer) files.

B4 - Control Workstations. [PF13].

B4A - Volume Assignments. [PF11]. Provides information on the status of users (workstations) paging location and paging file type. Provides for overriding the system paging volume algorithm. Can also assign a specific interactive task to a volume for paging.

B5 - System Options. [PF14].

B5A - Set System Parameters. [PF4]. Provides the commitment ratio (CR). An acceptable range is 100 - 999 (this is a percent).

B5B - Display Systems Status. [PF5]. Provides the amount of physical memory in the system, bad 2 kB areas in memory, amount of memory permanently fixed (used by the OS etc), the amount of memory temporarily fixed, the SHARER buffer pool hits, misses, the SHARER control blocks, and VTOC cache hits and misses.

B5C - Display System Versions. [PF7]. Provides the version numbers of the OS components and indicates if compatibility problems exist between the components.

C - <u>POOLSTAT utility</u>. Provides information on the usage of page pools by volume. For each volume the following information is provided.

- volume name

- page pool size (capacity)
- current usage of the page pool
- peak usage since last IPL
- memory commitment (the total MDA assigned to the page pool)
- the users (tasks) using the page pool
- the reference rate during the last second (times the system read from or wrote to the page pool) and the same only for longer record times.

D - RESTORE utility. Consolidates file and free extents. Can be used to selectively position files on a disk using the NOCOPY option (6).

E - COPY utility. When used with the REORG option, it deletes records marked for deletion, corrects block splits, and reestablishes growth space for files with packing factors less than 100%. Can also be used to change the packing factors or compression setting for a file (6).

F - IOTRACE utility. Provides historical information on I/O activity for a specified device.

G - IOELOG utility. Provides historical information of I/O errors for a specified device.

H - FASTLINK utility. Provides information of the files kept permanently open - file name, library, volume, total usage, and active users. Also allows you to modify these conditions.

I - SHRSTAT utility. Provides information on the use of the SHARER. The following information is provided.

Buffer pool information:

- number of buffer pools
- hit count
- miss count
- hit/miss ratio

Sharer memory pool information:

- current memory allocated for the SHARER program.
- least memory allocated for the SHARER.
- when peak SHARER load occurred

DMS requests processed:

- Open, close, read, write, rewrite, delete, start, and advance sharing

Other information:

- total number of requests made to the sharer
- current number of SHARER users

- maximum number of SHARER users
- current number of open files
- maximum simultaneous open files
- fixing mode for SHARER control blocks and buffers.

J - DISKMAP useraid. Provides a listing of extents in the order they are listed on a volume. May not be available on all systems. For each extent the following is provided.

- blocks allocated
- file in each extent
- library of each file
- type of file

K - DISKUSE utility. Provides information on the volumes in the system - number, name, percentage of utilization, number of files and libraries on each, number of allocated and free blocks available.

L - DISKINIT utility. Can be used to specify (create or change) page pool size and location (by disk and by location on disk). Sets the disk fault tolerance setting.

M - GENEDIT utility. Can be use to

- set the size of the MDA
- set the number of sharer control blocks.
- fix sharer buffers.
- to set the VTOC cache size.

N - LISTVTOC utility. Provides the following information for individual volumes.

- extents of individual files
- space available in blocks
- number of free extents
- number of libraries
- number of files

O - Security Logging Facility. Provides a means of recording and controlling user activities.

Controls:

- assigns modifiable data (MDA) for a specific user different than the default value.

Recording:

- file opens
- opens for modifications
- file closes
- file renames

- file deletes
- file protects
- files printed through DP
- programs run
- procedures run
- background jobs run
- invoked tasks
- logons
- logoffs
- mounts
- dismounts
- and others

P - FILEDISP utility. Can locate @SYSPAGE libraries.

Q - Compress-In-Place utility. Provides some reduction in file fragmentation (6).

(The above material was obtained by direct experimentation with a Wang VS computer or from reference 26, unless other indicated)

# Appendix C: Questionnaire

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OH 45433-6583

12 JUN 1990

REPLY TO ATTN OF: LSM

SUBJECT: Wang Computer Performance Questionnaire

TO:

1. Please have your WIMS system administrator complete the attached questionnaire and return it by 30 Jun 90.

2. Purpose. This questionnaire is intended to collect data on base level Wang computer performance attributes. In this context, performance means essentially speed--how fast can the computer perform its work. The information you provide will be used to create improved guidelines for tuning our base level systems and to clarify future hardware and software requirements.

3. Completion Time. It should take less than 5 hours to complete this questionnaire. Although lengthy in appearance, many parts will not apply to your base or will not be required by your base. The primary purpose for the questionnaire is to collect data. However, the questionnaire was also prepared as a tutorial on performance. Completing the questionnaire should be a very valuable learning exercise for your system administrator. The whole questionnaire is sent so you can take advantage of the whole tutorial even though we are collecting your data for only a portion of the questionnaire.

4. Your cooperation is greatly appreciated. We are working very closely with the Air Force Engineering and Services Center on this research. The results of this study could have great impact on the structure of our computer assets and provide significant improvements in the next generation Civil Engineering computer systems. Please complete the questionnaire and return it promptly.

RICHARD S. CAMMAROTA, Colonel, USAF
Dean
School of Systems and Logistics

1 Atch
Performance Questionnaire

STRENGTH THROUGH KNOWLEDGE

WIMS Performance Questionnaire and Tutorial

3 Jun 90

Purpose. The information you provide through this questionnaire will be used to provide an Air Force assessment of certain performance aspects of the CE Wang/WIMS. The information may be used to plan future training, hardware, and software, assess current operating proficiency and efficiency, and develop additional guidance on performance analysis and tuning. This document was also written as a tutorial on performance. Hopefully, you will find it interesting and beneficial.

Performance. For the purpose of this questionnaire, performance means speed - how fast a computer is accomplishing work for the user. A direct measure of performance is the time it takes to refresh a screen after pressing <enter> or a function key.

Non-attribution and Data Accuracy. The information in this report will **not be attributed to your base** unless you authorize it. This questionnaire is not intended as an inspection or report card for you or your unit. The information you provide will be combined with others to get an Air Force wide performance assessment. It is very important that you answer this questionnaire based on current operating procedures, practices, knowledge, and system condition. Please **do not make any special (beyond what you normally do) adjustments to your system** prior to completing this survey.

Report completion. You should be able to complete this questionnaire in less than 5 hours. Please return this questionnaire even if you are unable to totally complete it. Note that only part of section II is to be completed.

Questions. If you have trouble with any portion of the questionnaire, please contact the individual listed below.

Phone Number: AV 785-8989
Wang Office Mail: Capt Reno T. Lippold, AFIT/LSM, Wright-Patterson

Need by Date. We're requesting the questionnaires be completed and returned by 30 Jun 90. We must receive the questionnaire before 15 Jul to include the data in our study.

Returning the questionnaire. The questionnaire should be returned to the address below.

AFIT/LSG
Attn: Capt Lippold
WPAFB, OH 45433-6583

## SECTION I

Please complete all parts in section I. It should take less than 1 hour and 30 minutes to complete this section.

PART 1. Background Information.

1. Your name (optional): ________________________

2. Telephone (optional): AV ____________________

3. Base (optional): ____________________________

4. Address (optional): _________________________

   _________________________

5. MAJCOM: SAC MAC TAC ATC AFSC AFLC AU

6. Unit size - number of military assigned: __________

   number of civilian assigned: __________

   Total: __________

PART 2. Information about the computer hardware at your base.

1. How many Wang mini computers serve your unit? (count only VS 6, 100, 7310 or 5000 (or similar) model computers, do not count Wang PCs.)

   0 1 2 3

(If you have no Wang VS computers - then you received the questionnaire by mistake. The remaining portions do not apply to your base.)

2. If you have more than one VS computer, please describe below as best you can how the different computers are interfaced. Diagrams are welcome.

**Note**. If your installation has more than one computer, select the one you feel is the most heavily used or the primary system to answer the remaining questions in this questionnaire.

3. What is the model of the computer?

VS 100 VS 7310 VS 5000 Other: ___________

(If the system is not one of the above, some portions of the questionnaire may not apply.)

4. How long has this computer system been operational?:

_________ years

5. How much physical memory does this computer have installed?:

_________ megabytes (MB)

(to determine the amount of memory, go into operator's mode and press PF14, System Options, at the Operator's Console. Then PF5, Display System Options. Take the number in the top line for page frames. Multiply this number times 2 (2 kilobytes per page frame) then divide by 1000 to get the total memory size.)

6. How many disk drives do you have connected to this computer?: (do not count floppies)

_________ drives

7. How many local (dual coax) work stations are connected to this computer? (do not count PCs):

_________ work stations

8. How many remote work stations are connected to this system?:

_________ work stations

9. How many micro computers (PCs) are connected to this computer (as local (dual coax) work stations)?

_________ PCs

10. Total work stations connected to this system (sum of the above):

_________ work stations

11. How many users are assigned to this computer?: _________

(If you have more than one system, estimate the users that would spend more than 50% of their terminal time working on this system.)

PART 3. Information on the software running on your system.

1. Mark yes to each of the following software packages if they are loaded and run on your system.

| | | |
|---|---|---|
| WIMS | yes | no |
| CEMAS | yes | no |
| PDC | yes | no |
| SABER | yes | no |
| RWP | yes | no |
| Wang Office Version: ________ | yes | no |
| WSN (Wang System Network) | yes | no |
| TCP/IP (DDN) | yes | no |

2. List below, in the following format, any software you have which is intended to assist with performance analysis or improvement. Examples are SAM, WORM, System Minder, VSSpace, and Space Saver. Include packages even if they no longer work due to the recent operating system upgrade.

**************************FORMAT*****************************

Name/Version of Software Pkg    Developed by (Company's Name)

Brief statement of primary functions ____________________

____________________________________________ Cost, if known

Then answer the questions/circle the best response.
**************************************************************

a. **Package 1**

Name: ____________________ By: ____________________

Functions: ______________________________________

____________________________________________ $ __________

How often do you use this product?: ____________________

Has this product improved the performance of your system?:

No    Not sure    Yes, a little    Yes, significantly

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | |

Considering cost, ease of use, and value, what is your overall assessment of this product?:

| very dissatisfied | dissatisfied | neutral | satisfied | very satisfied |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

b. **Package 2**

Name:____________________ By: ____________________

Functions: ________________________________________

____________________________________ $ __________

How often do you use this product?: ____________________

Has this product improved the performance of your system?:

| No | Not sure | Yes, a little | Yes, significantly |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

Considering cost, ease of use, and value, what is your overall assessment of this product?:

| very dissatisfied | dissatisfied | neutral | satisfied | very satisfied |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

c. **Package 3**

Name:____________________ By: ____________________

Functions: ________________________________________

____________________________________ $ __________

How often do you use this product?: ____________________

Has this product improved the performance of your system?:

| No | Not sure | Yes, a little | Yes, significantly |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

Considering cost, ease of use, and value, what is your overall assessment of this product?:

| very dissatisfied | dissatisfied | neutral | satisfied | very satisfied |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

d. **Package 4**

Name: ____________________ By: ______________________

Functions: ____________________________________________

________________________________________ $ __________

How often do you use this product?: _______________ __

Has this product improved the performance of your system?:

| No | Not sure | Yes, a little | Yes, significantly |
|---|---|---|---|
| 1 | 2 | 3 | 4 |

Considering cost, ease of use, and value, what is your overall assessment of this product?:

| very dissatisfied | dissatisfied | neutral | satisfied | very satisfied |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

3. What is your operating system (OS) version?: _________

PART 4. Information about those who directly manage your computer system.

1. How many people, including yourself, are involved in computer management? (system administration, system operation):

1 2 3 4 5 6

2. List below the types of formal training that you or any of the people counted above have had that relates to computer management. Examples are Mgt 003, System Administrator's Course or Wang Inc courses.

a. ________________________________________

b. ________________________________________

c. ________________________________________

d. ________________________________________

e. ______________________________

3. Based on the above information, fill in the following matrix. Grade is rank or civilian grade such as GS-4. Yrs Exp is the number of years experience managing Wang VS computers. Hours Per Week is the average number of hours worked by the person on **computer matters**. (If the person normally works 50 hours per week but 20 of those hours are spent on other duties not related to computer management, list 30.) Under Training, list the letters corresponding to the training items listed above.

| | Grade | Yrs Exp | Hours Per Week | Training |
|---|---|---|---|---|
| Person 1 | ____ | ____ | ____ | ____ |
| Person 2 | ____ | ____ | ____ | ____ |
| Person 3 | ____ | ____ | ____ | ____ |
| Person 4 | ____ | ____ | ____ | ____ |
| Person 5 | ____ | ____ | ____ | ____ |
| Person 6 | ____ | ____ | ____ | ____ |
| Totals: | | ____ | ____ | |

PART 5. Local activity that may affect computer performance.

1. Fill in the information requested for each administrative maintenance task (some call this batch work) listed.

(Put NA for nonapplicable items. "Average times done per week" means the average number of times the task is performed per week. If you do incremental backups each duty day (not Saturday or Sunday) then the number would be 5. "Operator time to complete one time" refers to the amount of time someone must spend to accomplish the task - or alternatively, the amount of time you would save if you did not do it. This is not the amount of time it takes from start to finish - which goes in the fourth column - unless the operator must work full time on this task while it is running. For the last column, we want to know if you accomplish these tasks during duty hours. Answer this with the percentage of times it is done during duty hours. For example, if you never do this task during duty hours then write 0%. If done mostly during the duty day then write an appropriate percentage such as 85%.)

| Admin Task Description | Average times done per week | Average Operator time to complete one time (minutes) | Average time duration each ops (minutes) | percent done during duty hours (%) |
|---|---|---|---|---|
| Full BACKUP | _____ | _____ | _____ | _____ |
| Incremental BACKUP | _____ | _____ | _____ | _____ |
| RESTORES | _____ | _____ | _____ | _____ |
| WIMS to BEAMS | _____ | _____ | _____ | _____ |
| BEAMS to WIMS | _____ | _____ | _____ | _____ |
| CEMAS end of day | _____ | _____ | _____ | _____ |
| WP Purge | _____ | _____ | _____ | _____ |
| File Reorg Jobs | _____ | _____ | _____ | _____ |
| Junk File Purge | _____ | _____ | _____ | _____ |

The above tasks were identified as tasks which could, in theory, be done during nonduty hours, to relieve the system of work burden. Please include other possible tasks below.

| | | | | |
|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ |

2. How many disks are normally involved in

a. your full backups: _________ disks

b. your incremental backups: _________ disks

PART 6. Computer performance assessment.

1. Do you receive complaints about the system as being slow or sluggish?

| Never | Rarely | Sometimes | Often | Very often |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

2. Based on user feedback, how do you think your users (on the average) feel about your computer's performance (speed)?

| Very dissatisfied | Dissatisfied | Neutral | Satisfied | Very satisfied |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

3. How do you personally feel about the performance of your computer system?

| Very dissatisfied | Dissatisfied | Neutral | Satisfied | Very satisfied |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

4. Prior to receiving this questionnaire, how would you describe local involvement with system performance issues?

| None | Minor | Moderate | Considerable | Extensive |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

## SECTION II

Please complete the four parts highlighted below. Instructions are attached. If you have time, you are encouraged to complete all parts. If you are not able to complete the four parts indicated, please return what you did accomplish. However, please complete PART 7 - it is very important. The other three parts were assigned at random for your base.

PART 7 - Baseline Performance Index

PART 8 - User Satisfaction and Work Impact

PART 9 - Wang VS Sharer Analysis

PART 10 - Wang VS VTOC Cache Analysis

PART 11 - Wang VS Disk Drive Analysis

PART 12 - Wang VS Fastlink Utilization

PART 13 - Wang VS Page Pool Analysis

PART 14 - Disk I/O Bottleneck Detection

PART 15 - File Packing Factor and Compression

These documents do not cover all aspects of performance. As a minimum, the following are excluded.

a. Programming concerns

b. Data file buffering

c. I/O error affects

d. User load affects

PART 7

## <u>Data Collection Instructions and Tutorial</u>

for

## <u>Baseline Performance Index</u>

5 Sep 90

1. <u>Purpose</u>. The purpose of this document is to describe a method of obtaining a 'performance index' for a Wang VS computer. The method described should work on all USAF Civil Engineering Wang VS computers.

2. <u>Completion Time</u>. The total time to complete this exercise should be less than 60 minutes.

3. <u>Background</u>. To accurately assess the performance of a computer system, the performance should be quantified. A number which describes the performance of your computer system is called a performance index. There are many possible ways to develop a performance index. Generally, more accurate methods are more complex. An accurate quantification of performance could be used to:

a. Monitor the performance of your system over time to determine if performance is improving or degrading.

b. Make a quantifiable comparison of your system performance before and after making a change to hardware, software, operations, or configuration. Changes in performance may be small and undetectable without measurements in many cases.

c. Provide numbers that could be used to compare your system to other similar systems. If another similar system had a significantly better performance index, you could then look for factors to explain the difference.

d. Provide numbers that could be used to provide economic evaluation or justification for performance improvement alternatives. (See Part 8 - User Satisfaction and Impact Survey)

For this exercise we present a very simple performance measurement method which is based on the time to compile a standard COBOL source code file.

4. <u>Data Collection Instructions</u>. Follow these directions to collect the data we need.

a. Select a day for collecting the data. The day you pick should be a typical duty day with an average amount of computer activity expected. Data will be collected 9 times during the day.

b. Near each of the times indicated, compile the work by facility program: MFACINQ in library MWOXSRC (probably on volume PGM001). Each time, measure the time, in seconds, to complete the compile operation after the last parameter has been provided. Also, record the number of interactive tasks currently running. (This is available through the Operator's Console using Interactive Tasks (PF6).)

Directions for compiling:

Set your INVOL (under Set Usage Constants) to the volume containing the FD (file descriptor) and SEL files - most likely PGM001.

Run REDITOR in Library USAFAIDS.

<u>1st Screen</u>:

Set Language = COBOL
File = MFACINQ
Library = MWOXSRC
Volume = PGM001 (probably)
**Plibrary = XXXJUNK**
Pvolume = SYS001
Scratch = yes <enter>

<u>2nd Screen</u>:

PF16 - Menu

<u>3rd Screen</u>:

PF10 - Compile the Edited Text

<u>4th Screen</u>:

Leave all fields as defaults <enter>

<u>5th Screen</u>:

Link = yes <enter>

<u>6th Screen</u>:

Verify the output is going to a junk library then press <enter> on the minute.

**Start timing**

(At this point the compilation should run to the end without interruption. If not, try to resolve the problem and rerun.)

| Local Time | Compile Time | Number of Interactive Tasks |
|---|---|---|
| 0800 | ________sec | __________ |
| 0900 | ________sec | __________ |
| 1000 | ________sec | __________ |
| 1100 | ________sec | __________ |
| 1200 | ________sec | __________ |
| 1300 | ________sec | __________ |
| 1400 | ________sec | __________ |
| 1500 | ________sec | __________ |
| 1600 | ________sec | __________ |

Total: __________sec (DE1)
(sum up all seconds)

Find the average. DE1/9 = ________sec

This number will be used as the performance index for your system.

5. Interpreting the Data. The number itself means little. Its value would be in comparisons with subsequent retests to determine change in performance. We will be using the number to compare similar systems within USAF to hopefully gain some insight into why similar systems perform differently.

6. Cautions and Tradeoffs. The above method was chosen for this exercise because it is very simple and is basically standardized for all computer systems. What may have been sacrificed is accuracy and freedom from erroneous results. If you wish to use this performance index method for your system, it should be used with caution. The validity of this performance measurement method has not been firmly established. The results of this questionnaire will provide a means of additional evaluation for this particular method.

7. Describe your agreement or disagreement with the statements below.

a. This idea was new to me.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

b. This should be a valuable tool for performance measurement.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

8. Prior to receiving this questionnaire, how would you describe local involvement with system performance measurement?

| None | Minor | Moderate | Considerable | Extensive |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

9. Comments. Any comments you have about this tutorial would be appreciated. In particular, we'd like to hear about disagreements you or others have with the information or ideas presented or success or problems you've had in this area of performance analysis and tuning.

File: survey7.doc

PART 8

## Data Collection Instructions and Tutorial

for

## User Satisfaction and Work Impact

5 Sep 90

1. Purpose. The purpose of this document is to describe a method of measuring user satisfaction and work impact as they relate to computer performance. The method described should work with all USAF Civil Engineering Wang VS computers.

2. Completion Time. The total time to complete this exercise should be less than 45 minutes.

3. Background. One question that should be answered when working performance issues is: What is the impact to my users due to the computer's speed? With the answer to this question you will (1) be able to assess the severity of the problem and thus properly prioritize your work in this area and (2) obtain data that will allow you to justify expenditures of time and money to improve performance and develop a means to quantify the value of improvements in performance.

a. You probably know how your users feel about the speed of your computer system. You receive a few compliments about how the system is running from day to day. Also you formulate your own assessment of the computer's performance based on the terminal work you do. With this, you develop a feel for the severity of the problem. But how accurate is this feel. Do the complaints you receive represent your unit in general or are they representative of only a small vocal group of users? What is the relative importance of performance compared to other responsibilities you have such as training, debugging, or system operation?

b. You can perform a more rigorous evaluation of the performance problem by conducting a survey of your users. The survey must be designed to collect information that can be quantified to determine answers to the above questions. You can survey all users or a sample of the users as long as the sample is randomly selected and large enough to ensure that the answers you get are representative of the unit in general.

4. Data Collection Instructions. Follow these directions to collect the data we need.

a. Send the following survey to your users. It was written to be sent over Wang mail. We recommend it be sent to a large percentage of

randomly selected users to ensure your responses reflect the unit overall. You may modify the introduction or ending and add questions to suit your taste as long as the wording of the 3 given questions remains unchanged.

PERFORMANCE SURVEY

---

This is a survey about system speed (performance). Please answer the questions below by replying with a memo listing the question numbers paired with the answers you select.

1. How satisfied are you with the speed (performance) of this computer system?

a. Very dissatisfied (1)
b. Dissatisfied (2)
c. Neutral - no opinion (3)
d. Satisfied (4)
e. Very satisfied (5)

2. Relative to other concerns you have about this computer system (such as training, user friendliness, data security, etc.), how important is system speed (performance) to you?

a. Least important (1)
b. Low importance (2)
c. Medium importance (3)
d. High importance (4)
e. Highest importance (5)

3. How much of your time, on the average, do you spend waiting on the computer during a normal duty day?

(If you feel you can't accurately estimate this time, please write down your waiting times as they occur and tally the results at the end of the day. If this was a typical day then this number would be a good response. Include only nonproductive waiting time. Example: If you wait for the computer on the average of 10 minutes each day but spend about half of that time preparing for the next input or some other useful task, then 5 minutes would be the average waiting time.)

a. less than 1 minute (1)
b. more than 1 minute but less than 4 minutes (2)
c. more than 4 minutes but less than 8 minutes (3)
d. more than 8 minutes but less than 15 minutes (4)
e. more than 15 minutes but less than 25 minutes (5)
f. more than 25 minutes (6)

Your response to this survey should look something like:

1. c
2. b
3. c

Thank you for your assistance.

(Your name)

---

b. Summarize the results of the survey:

Survey sent to _________ users

Number of replies received: _________ replies

(Some people may respond to the survey but may not answer all questions. Count them as one reply above, but for any unanswered questions, count them as "not answered" for that question.)

For each question list the number of each answer.

Question 1.

a responses: _____ b responses: _____

c responses: _____ d responses: _____

e responses: _____ not answered: _____

Question 2.

a responses: _____ b responses: _____

c responses: _____ d responses: _____

e responses: _____ not answered: _____

Question 3.

a responses: _____ b responses: _____

c responses: _____ d responses: _____

e responses: _____ f responses: _____

not answered: _____

5. Interpreting the Data.

a. Question 1. Examining the summary above should give you some better insight into how your users feel about performance. You could assign each a score 1 up to 5 (or 6) and then use these weightings to calculate the average response. This number would be more useful if compared with other averages of similar questions on different subjects such as training or trouble shooting system problems. This would allow you to determine the relative importance of various computer related issues as seen by your users. Additionally, if the number of a and b responses is high you might want to see if these came primarily from a particular group of users such as customer service or secretarial. A pattern might signal the need to investigate further the problems of a particular user group rather than the system in general.

b. Question 2. Can be analyzed in much the same way as Question 1. Obviously the primary purpose of this question is to determine the relative importance of the performance issue.

c. Question 3. The purpose of this question is to allow the calculation of the approximate average daily waiting time per user. Such a number would be useful for economic evaluations. For example, assume you have 100 total users and their average delay time was calculated as 180 seconds per day. Making an assumption that this time is truly wasted you could estimate a cost of this time using an average shop rate such as $15 per hour. A monthly cost due to these delays would then be:

100 users x 180 sec/day x 20 days/month x 15 $/hr x
1 hr/3600 sec = $1500 per month.

(The above calculation assumes that if the delays were lessened the time gained would be put to productive use. Also other costs due to system delays, such as user frustration, job dissatisfaction, or customer dissatisfaction are not included.)

If you randomly surveyed 20 users, 20 responded, and the average daily waiting time was 180 seconds, then this could be used to estimate the average for all your users. If some surveyed do not respond or answer this particular question, then a judgement will have to be made as to what to do with these nonrespondents. You could take the numbers you do receive and calculate an average delay per respondent and use that as the overall average, but it seems likely that your result will be high. We believe that many who do not respond will be those who do not use the computer much, if at all, and therefore are affected very little by performance. A conservative approach would be to assign a value of 0 delay for all those who do not respond to this question.

6. Cautions. Any survey instrument is subject to error. In this case we are allowing the users to estimate their waiting times. The answers provided could deviate wildly from the true values. Since we are only

interested in the average, we hope that over estimations will be roughly compensated by under estimations. A more accurate but much more time consuming method of obtaining this same information would be to observe a random sample of your users and record their waiting times.

7. Describe your agreement or disagreement with the following statement.

This information was new to me.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

8. Prior to receiving this questionnaire, how would you describe local involvement with user satisfaction and impact assessment?

| None | Minor | Moderate | Considerable | Extensive |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

9. Comments. Any comments you have about this tutorial would be appreciated. In particular, we'd like to hear about disagreements you or others have with the information and ideas presented or success or problems you've had in this area of performance analysis and tuning.

File: survey8.doc

PART 9

## Data Collection Instructions and Tutorial

for

## WANG VS Sharer Analysis

5 Sep 90

1. Purpose. The purpose of this document is to describe a method of analyzing 'Sharer' activity on a Wang VS computer to optimize performance. The method described should work on all USAF Civil Engineering Wang VS computers.

2. Completion Time. The total time to complete this exercise should be less than 30 minutes. One terminal will be tied up for 60 minutes.

3. Background.

a. The Wang VS computer runs a program called Sharer which allows multiple users to work on the same data file. By allowing shared use, only one copy of the data has to be in memory so memory space and I/O operations are saved. An area in memory is set aside to hold this shared data and is called the 'Sharer Buffer Pool'. Shared information most recently used is placed in the pool. If it gets full, older data is written over by new. Whenever a program needs shared data it looks to the Sharer buffer pool first to see if the data it needs is there. If it is, it takes it from the pool thus preventing a physical disk read. This saves time. The larger the Sharer buffer pool, the more data that can be stored there, and the more likely data will be in it when needed. The Sharer buffer pool is established automatically during the system Initial Program Load (IPL). The Sharer buffer pool size and configuration can be controlled by the system administrator. (14, 9:2.13)

b. GENEDIT has a minor bug in that the number of 2 kB blocks of memory (called buffers in the program) requested is doubled on the actual system. (Asking GENEDIT for 100 buffers results in establishing 200 buffers (13).

4. Data Collection Instructions. Follow these directions to collect the data we need.

a. Select a day for collecting the data. The day you pick should be a typical duty day with an average amount of computer activity expected. Data will be collected twice over a period of one half hour.

b. Run the SHRSTAT utility at approximately 1000L to get the following information.

# of buffers: _____

Buffers fixed: yes no

Control blocks fixed: yes no

(1) Collect data on Sharer hits and misses to determine the Sharer 'hit ratio' and miss rate. The hit ratio is the number of times Shared data was found in the Sharer buffer pool divided by the number of times the system looked there. For example, if the system looked in the buffers 100 times and found what is was looking for 60 times (the other 40 times it had to go to the actual data on disk) the hit ratio would be 60/100 = 0.6. The miss rate is the number of times per second that a miss occurs.

(2) Reset the hit and miss count by pressing PF1 (start on the minute)

Time : ________L (DE1)

(3) After approximately one hour, press <enter>, and copy down the hit and miss figures.

Hits: ______________(DE2) Misses: _____________(DE3)

Time: __________L (DE4)

Elapsed time = DE4 - DE1 = _______________ minutes (DE5)

Elapsed seconds = DE5 x 60 = ____________ sec (DE6)

(4) Divide the hit count by the sum of the hits and the misses (total tries). The resulting number is the average hit ratio for the period.

Hit ratio: $\frac{DE2}{(DE2+DE3)}$ = .____ (should be between 0 and 1)

This number represents the fraction of times the system looked in the Sharer buffers and found what it needed.

(5) Divide the number of misses by the number of seconds to get the miss rate.

Miss rate: DE3/DE6 = _____ misses per second

(Note that Sharer hit and miss information is also obtainable from the Operator's Console under System Options. Miss rates and hit ratios

would be calculated as for the VTOC cache. This would permit you to free up the terminal during the test period. (see Part 10, VTOC Cache Analysis)).

5. Interpreting the Data.

a. The key statistic is the miss rate. A rule of thumb used by one SSA is to add Sharer buffers if the miss rate is greater than 5 misses per second. The statistic of secondary importance is the hit ratio. The higher it is the better, in general. Ideally it should be above .75. However, achieving this may be difficult or impossible. A ratio greater than .9 is considered nonproductive. If the miss rate is low (less than 3 misses per second) the hit ratio is less important. One WIMS system administrator recommends that the number of buffers generally be maximized at 255 (3). If the miss rate is low and the hit ratio is high, you may want to decrease the number of Sharer buffers. Chances are this memory will do much more good if freed up for non-shared paging.

b. If your buffers are fixed, and you do not have a large amount of system memory (memory poor), you might consider unfixing them. Some believe that in a WIMS environment the Wang VS runs better with unfixed buffers (3).

c. If your buffers are not fixed and you have a large of amount of memory (memory rich), you might try fixing them. Fixing the buffers will speed up shared file operations.

(See Little z document 105 (ref 14) for a rule of thumb determining if your system is memory rich or poor)

d. It is generally considered best to fix your control blocks. The control blocks take up little memory and little is gained by freeing them for other tasks (9:2-17, 3).

e. If you cannot increase the buffer pool size without degrading the performance of the system overall, you would need to install additional memory to take advantage of additional Sharer buffers.

6. Cautions and Tradeoffs. Increasing the buffer pool size should improve the performance of operations using shared files but may slow others. This is especially true if you fix the buffers. A large buffer pool places additional overhead on the central processor (9:2.15).

7. Describe your agreement or disagreement with the following statement.

This information was new to me.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

8. Prior to receiving this questionnaire, how would you describe local involvement with Sharer analysis and tuning.

| None | Minor | Moderate | Considerable | Extensive |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

9. Comments. Any comments you have about this tutorial would be appreciated. In particular, we'd like to hear about disagreements you or others have with the information or ideas presented or success or problems you've had in this area of performance analysis and tuning.

File: survey9.doc

## PART 10

## Data Collection Instructions and Tutorial

for

## Wang VS VTOC Cache Analysis

5 Sep 90

1. Purpose. The purpose of this document is to describe a method of analyzing the 'Volume of Table Contents (VTOC) cache' on a Wang VS computer to optimize performance. The method described should work on all USAF Civil Engineering Wang VS computers.

2. Completion Time. The total time to complete this exercise should be less than 20 minutes.

3. Background. When a computer looks for information on a disk it must first find the location of that information by reading in location data from the VTOC - an area on the outer edge of each disk. This operation, which involves physically moving a disk read-write head, adds to the total time required to read in the data. If many read operations are occurring, the total increase in response times can be significant. The Wang VS has the capability to store VTOC data in memory - which can be accessed there more rapidly. An area in memory set aside to hold this VTOC data is called a VTOC cache. Information most recently read from a disk VTOC is placed in this cache. If it gets full, older VTOC information is written over by new. When ever a program needs information from a disk it looks to the VTOC cache first to see if the file location data it needs is there (4:2.5). If it is, it takes it from the cache thus preventing a physical disk read. This saves time. Access time to main memory is around 1 microsecond. Access time to the disk is generally from 10 to 100 milliseconds or about 50000 times longer (1:278). The larger the VTOC cache, the more VTOC data that can be stored there, and the more likely data needed will be in it. The VTOC cache is established automatically during the system Initial Program Load (IPL). VTOC cache size can be controlled by the system administrator. (14, 4)

4. Data Collection Instructions. Follow these directions to collect the data we need.

a. Select a day for collecting the data. The day you pick should be a typical duty day with an average amount of computer activity expected. Data will be collected twice over a period of one half hour.

b. Determine the number of 2 kB blocks of memory (buffers) assigned to the VTOC cache by examination of your configuration file. Run GENEDIT and select PF2 - Examine System Options.

Number of buffers: __________

c. Collect data on VTOC hits and misses to determine the VTOC cache hit ratio and the miss rate. The hit ratio is the number of times VTOC location data was found in the cache divided by the number of times the system looked there. For example, if the system looked in the VTOC cache 100 times and found what is was looking for 60 times (the other 40 times it had to go to the actual VTOC on a disk) the hit ratio would be 60/100 = 0.6. The miss rate is the number of misses occurring per second.

(1) Near 1400 on the day you select, record the current status of past hits and misses in the VTOC Cache. To determine this baseline, go into operator's mode to the Operators Console screen. Press PF14, System Options, then PF5, Display System Status. You should be at a screen giving the hit and miss count for the **VTOC cache.** Copy the data below:

Beginning figures:

Hits: ______________(DE1) Misses: _____________(DE2)

Time of Day: __________L (DE3)

(Both the hit and miss count will reset to half when they reach 65535 (8:8.4) If the number above is near 65535 you may have to pick another day or time to collect the data.)

(2) One half hour later, near 1430, recheck these figures.

Ending figures:

Hits: _____________(DE4) Misses: _____________(DE5)

Time of Day: __________L (DE6)

(3) Now determine the total number of hits and misses that occurred during the hour.

Hits in the period = DE4 - DE1 = ______________(DE7)

Misses in the period = DE5 - DE2 _______________(DE8)

Elapsed time = DE6 - DE3 = _________ minutes (DE9)

Elapsed seconds = DE9 x 60 = __________ seconds (DE10)

(4) Divide the hit count by the sum of the hits and the misses (total tries). The resulting number is the average hit ratio for the period.

Hit ratio: $\frac{DE7}{(DE7+DE8)}$ = .____ (should be between 0 and 1)

This number represents the fraction of times the system looked in the VTOC cache and found what it needed.

(5) Divide the number of misses in the period by the number of seconds to get the miss rate.

DE8/DE10 = _______ misses per second

This number represents the number of times per second the system must perform a VTOC I/O.

5. Interpreting the Data. The miss rate is the most important statistic. A rule of thumb used by one SSA is to keep it below 4 per second if possible. The hit ratio is a secondary statistic. In general you want a high ratio, above .75. If the miss rate is low, the hit ratio is less important. If your miss rate is consistently above 4 per second, you may want to increase the number of cache buffers. If it is consistently low, you may want to consider reducing the number of cache buffers. Chances are this memory will do much more good if freed up for system paging. (9:2.20)

6. Cautions and Tradeoffs.

a. Increasing the VTOC cache size reduces the amount of memory available for tasks to store code and data for running programs. Reducing the amount of memory available for these functions may increase paging rates which might negate any speed improvement and in fact could cause an overall slow down. Only increase the VTOC cache size if paging activity is acceptable. Then, if you do increase it, do it in small increments and monitor the system paging rate and overall system performance after each change.

b. If you cannot increase the VTOC size without detrimental impact on the overall system performance then you would have to install additional memory to take advantage of a larger VTOC cache.

7. Describe your agreement or disagreement with the following statement.

This information was new to me.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

8. Prior to receiving this questionnaire, how would you describe local involvement with VTOC cache analysis and tuning?

| None | Minimal | Moderate | Considerable | Extensive |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

9. <u>Comments</u>. Any comments you have about this tutorial would be appreciated. In particular, we'd like to hear about disagreements you or others have with the information or ideas presented or success or problems you've had in this area of performance analysis and tuning.

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PART 11

<u>Data Collection Instructions and Tutorial</u>

for

**<u>WANG VS Disk Drive Analysis</u>**

5 Sep 90

1. <u>Purpose</u>. The purpose of this document is to describe a method of analyzing your disks drives on a Wang VS computer to optimize performance. The method described should work on all USAF Civil Engineering Wang VS computers.

2. <u>Completion Time</u>. The total time to complete this exercise should be less than 30 minutes.

3. <u>Background</u>. Several issues that can affect system performance are disk file fragmentation, file placement on the disks, free space available on the disks, and disk fault tolerance settings. These are the subjects of this exercise.

a. <u>File and Free Space Fragmentation</u>.

(1) When a file is stored on a disk it may often get split up into pieces. When a file is broken up on a disk it is said to be fragmented. The different pieces of the files are called extents. When many files are fragmented, performance can degrade. Head seek time from the current extent to the VTOC and then to the next extent causes most of the additional delay (13). Likewise free space on your disk can get fragmented into small chunks. This also degrades performance by slowing the writing of new or expanded files. Generally, if your free space is fragmented, your actual files will be fragmented also.

(2) Fragmentation of individual files can be assessed using the LISTVTOC utility and displaying a file list. Information on free space fragmentation is available through the Manage Files/Libraries function of the Command Processor.

(3) Fragmentation of a disk can be reduced in two ways. Running the Compress-In-Place (CIP) utility can solve the problem partially (8:14.1-14.5), however, some SSAs have had problems with CIP (13). The best solution is to run a full BACKUP and RESTORE on the disk. This consolidates both file and free extents (2).

b. <u>File Placement</u>.

(1) When data is retrieved from or written to a disk, the read-write heads in the disk drive must move to the proper cylinder from the

location of the last file worked on. This physical movement takes time and the farther apart the two files (or two extents of the same file) the more time it takes. To speed up this operation it is desirable to have your most active files close together on the disk. Since the VTOC is on the outer edge of the disk and is also frequently accessed, it would generally be advantageous to put the most active files close to the VTOC. Conversely, inactive files, such as COBOL source code, should be displaced away from the active region toward the center of the disk. Note that page pools would also work best by placing them on the outer disk edge (see Part 13, Page Pool Analysis).

(2) The DISKMAP useraid can be used to find out where your files are located on a disk - if you have it.

(3) To identify frequently accessed files, look in the interactive task screen in Operator's Console over a period of time, and the frequently used files will become familiar quickly (13).

(4) Repositioning files can be accomplished during a RESTORE operation by manually restoring the libraries you want closest to the VTOC and then the rest using the NOCOPY option (22).

(5) This whole process is fairly time consuming but is essentially a one time requirement. Once the libraries are placed near the VTOC, they stay there through backups and restores.

c. <u>Available Free Space</u>. Disks which become too full can indirectly cause performance problems. When the free space on a dynamic disk gets low, file expansions will cause fragmentation to a much larger degree than when ample expansion room exists. The solution, of course, is to create more free space. In some cases the only solution may be to purchase additional disk storage. This should be considered a last resort and other methods should be used when practical. Free space on a disk can be assessed using the DISKUSE utility (or useraid) or by the LISTVTOC utility. The following options are open to the system administrator:

(1) Archive unused data.

(2) Delete software or data that is rarely used - store it on tape or disk and reload as the need arises.

(3) Use the COPY utility with REORG parameter on data files to delete records that are marked for deletion.

(4) Reduce the size of your page pools if they are excessively large (see Part 13, Page Pool Analysis).

(5) Use compressed files with 100% packing factor for infrequently modified data files or files that normally have records added only to the end of the file.

(6) Libraries can be moved to different disks.

d. Disk Fault Tolerance Settings.

(1) Each disk has a space on the outer edge called the volume table of contents or VTOC. This area on the disk contains location information for the files on that disk. This is very important as without it your system cannot locate or access the files on the disk. If the VTOC becomes damaged you may loose some or all of your files on the disk. To guard against such losses, the Wang VS has the capability to maintain more than one VTOC. If one is damaged, the others can than be used to get the location information. The protection for the VTOCs is called the disk fault tolerance setting.

(2) There are three levels of protection. No setting provides one VTOC. The next level is called 'crash' and provides two VTOCs. The highest protection is called 'media' and provides four VTOCs, two pairs on separate cylinders (12:6.21). While the higher protection may seem desirable, there is a price to be paid in performance as you go up in protection level. When you make a change to a file, the VTOC will often need to be updated. Any VTOC modifications must be made to each VTOC in turn. More VTOCs means more time to complete file modifications and also more disk space consumed.

(3) Media tolerance has the VTOC information on separate cylinders, therefore, disk movements are necessary to update all the VTOCs. This means a significant difference in modification times between media and crash. Crash protection provides two VTOCs, but they are on the same cylinder and the information is interleaved meaning modification time is only slightly higher than for no protection. Crash protection is generally considered adequate. If your system is on UPS (power loss is one cause of VTOC damage) and/or you do daily backups, you might consider using no special protection to gain a performance and space advantage. However, apparently little can be gained in performance by going from crash to no protection (13, 12:6.22). A disk which is primarily used for static files and temporary files (work files, paging files, and spooling files) would be a good candidate for no protection. Note that a disk with little file alteration activity would have few VTOC alterations and thus little would be gained by lowering the protection. Gains can only be made by lowering protection on disks with changing files. Lost data through damaged VTOCs is rare but does happen. Through this questionnaire, we hope to determine how probable such an event is.

(4) A disk's protection level is set by the system administrator during initialization using the DISKINIT utility. The current settings of each disk can be found through the Operator's Console by selecting Manage Disks, (PF10).

4. Data Collection Instructions. Follow these directions to collect the data we need.

a. Go to the Command Processor screen. Press PF5, Manage Files and Libraries, then position the cursor on each volume in turn, and press PF12, Display Free Extents. Fill in the following blanks.

Volume __________ contains _____ free extents totalling

__________ blocks.

Size of largest extent: __________ blocks (first one listed)

Size of smallest extent: __________ blocks (last one listed)

Volume __________ contains _____ free extents totalling

__________ blocks.

Size of largest extent: __________ blocks (first one listed)

Size of smallest extent: __________ blocks (last one listed)

Volume __________ contains _____ free extents totalling

__________ blocks.

Size of largest extent: __________ blocks (first one listed)

Size of smallest extent: __________ blocks (last one listed)

Volume __________ contains _____ free extents totalling

__________ blocks.

Size of largest extent: __________ blocks (first one listed)

Size of smallest extent: __________ blocks (last one listed)

Volume __________ contains _____ free extents totalling

__________ blocks.

Size of largest extent: __________ blocks (first one listed)

Size of smallest extent: __________ blocks (last one listed)

Volume __________ contains _____ free extents totalling

__________ blocks.

Size of largest extent: __________ blocks (first one listed)

Size of smallest extent: __________ blocks (last one listed)

Volume __________ contains _____ free extents totalling

__________ blocks.

Size of largest extent: __________ blocks (first one listed)

Size of smallest extent: __________ blocks (last one listed)

Volume __________ contains _____ free extents totalling

__________ blocks.

Size of largest extent: __________ blocks (first one listed)

Size of smallest extent: __________ blocks (last one listed)

b. Go to the Operator's Console and press PF10, Manage Disks. The screen will provide names, size and fault tolerance setting for each disk. Fill in the first three columns below with this data.

c. Run the DISKUSE utility for each disk drive (if you have it) and fill in the last column indicating how full the disk is. If DISKUSE is unavailable run LISTVTOC on each drive.

| Volume Name (MB) | Disk Size | Disk Status: | % Full |
|---|---|---|---|
| __________ | __________ | __________ | __________ |
| __________ | __________ | __________ | __________ |
| __________ | __________ | __________ | __________ |
| __________ | __________ | __________ | __________ |
| __________ | __________ | __________ | __________ |
| __________ | __________ | __________ | __________ |
| __________ | __________ | __________ | __________ |
| __________ | __________ | __________ | __________ |

d. Is your system (CPU and drives) on uninterruptible power (UPS)?:

yes no

e. How many times in the past have you received an "unreliable VTOC" error. (go back as far as you or others can accurately remember)

Number of unreliable VTOC errors: __________ over the time span of

__________ months.

f. Of the incidents counted in e, how many were verified as true errors using LISTVTOC?:

__________

g. Of the incidents counted in e, how many resulted in lost data when the fault tolerance of the affected disk was crash?:

__________

h. Of the incidents counted in e, how many resulted in lost data when the fault tolerance of the affected disk was none?:

__________

i. Of the incidents counted in e, how many resulted in lost data when the fault tolerance of the affected disk was media?:

__________

j. Have you or anyone else ever gone through the process of identifying frequently accessed files and then positioning them together (as described in paragraph 3b above)?

a. yes b. no c. not sure

5. Interpreting the Data.

a. Fragmentation. Keeping free extents under 10 is desirable but is difficult to maintain. Some SSAs use 20 as a desirable number to stay below. (13) Several SSAs consider 100 free extents on a 288 MB drive as an upper bound on free extents.

b. Free Space. A disk drive over 80% full is generally considered too full (13). Try not to let disks get fuller than this.

c. Fault Tolerance. Media tolerance should be avoided. If you backup certain disks frequently and/or are on a UPS, you might consider going from crash tolerance to none. Since the system disk is so important it should be left with crash tolerance (13).

6. <u>Cautions and Tradeoffs</u>. Obviously file maintenance activities such as BACKUP and RESTORE take considerable time and if done during duty hours will affect system performance themselves. Thus the impact of these actions should be balanced against the expected gains. Lowering disk fault tolerance levels should only be done if you understand and accept the additional risk incurred.

7. Describe your agreement or disagreement with the following statement.

This information was new to me.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

8. Prior to receiving this questionnaire, how would describe local involvement with the performance analysis and tuning ideas expressed in this Part?

| None | Minimal | Moderate | Considerable | Extensive |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

9. <u>Comments</u>. Any comments you have about this tutorial would be appreciated. In particular, we'd like to hear additional ideas or disagreements you or others have with the information or ideas presented or success or problems you've had in this area of performance analysis and tuning.

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PART 12

## Data Collection Instructions and Tutorial

for

## WANG VS FASTLINK Utilization

5 Sep 90

1. Purpose. The purpose of this document is to describe a method of analyzing 'FASTLINK' utilization on a Wang VS computer to optimize performance. The method described should work on all USAF Civil Engineering Wang VS computers.

2. Completion Time. The total time to complete this exercise should be less than 25 minutes.

3. Background. The FASTLINK utility allows you to keep specified files permanently open. Properly used, this feature can improve system performance.

a. When a user issues a command to open a file (starting a program or manipulating a data file), the system must locate the file by examining the volume table of contents (VTOC) and must allocate control blocks for the file. This takes time. If a file is opened frequently, the access speed will be improved for that file if it is kept permanently open.

b. To maximize the benefit from FASTLINK, you want to select files that are frequently used but only open for short time intervals. An example of such a file could be the Report utility. Normally, it would be run by a user for a short time to find a file. If the REPORT utility was being used many times during the day, it would be a candidate for FASTLINK. Infrequently used programs such as BACKUP would not be good selections for FASTLINK. Also, programs, such as Wang WP (word processing), that are used often but are run for a long time by each user would generally not benefit from FASTLINK. (7, 13)

c. One way to determine the best files for FASTLINK is to select those you feel might be candidates, include them in FASTLINK, monitor them over time, and delete those that do not have the proper usage characteristics.

4. Data Collection Instructions. Follow these directions to collect the data we need.

a. Do you normally run with files permanently open?: (if you're not certain, read item 'c' below.)

yes no

If the answer to the above question is no, you are done collecting information for this Part of the Questionnaire. If you do use FASTLINK, provide information on the programs you have permanently open as follows:

b. Select a day for collecting the data. The day you pick should be a typical duty day with an average amount of computer activity expected. Data will be collected four times during the day.

c. Each time you collect the data perform the following steps:

- run program FASTLINK.

- Press PF1, Display Perm-Open Pgms. This will display a list of current files that are kept permanently open by FASTLINK.

(If the list is blank and you are not aware of canceling any permanently opened files since last IPL then you probably do not normally have files that are kept permanently open.)

d. Day Start. Complete the following items at the beginning of your typical duty day.

Local Time: __________ (DE1)

Total number of files perm open: _______ files

(If you have more than 10 files open just list the first 10 below but provide the actual total above.)

| | Perm Open File Name | Library | Volume | (Day Start) Total Usage |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |

e. <u>Mid morning and mid afternoon</u>. Run FASTLINK and Display Perm-Open Pgms again to determine the number of active users (last column on the screen) of the permanently opened programs sometime between 0900L and 1100L (mid morning) and then again between 1300L and 1500L (mid afternoon).

| | Mid morning | Mid afternoon |
|---|---|---|
| Time data was collected: | ________L | ________L |

| File No. | Number of Mid Morning Active Users | Number of Mid Afternoon Active Users |
|---|---|---|
| 1 | ________ | ________ |
| 2 | ________ | ________ |
| 3 | ________ | ________ |
| 4 | ________ | ________ |
| 5 | ________ | ________ |
| 6 | ________ | ________ |
| 7 | ________ | ________ |
| 8 | ________ | ________ |
| 9 | ________ | ________ |
| 10 | ________ | ________ |

f. <u>Day End</u>. Now, at the end of the duty day, collect the new file usage figures so that the average usage during the day can be calculated.

(1) Recopy the (Day Start) Total Usage figures from the first table to column 3 of the following table.

(2) Find the (Day End) Total Usage by calling up the Display Perm-Open Files screen.

(3) For each file, subtract column 3 from column 2 to get col 4.

(4) Finally, divide column 4 by the number of hours from beginning to end.

Time final data collected: ________L (DE2)

Duration of collection: DE2 - DE1 = ________ hours (DE3)

| 1 | 2 | | 3 | | 4 | | | 5 |
|---|---|---|---|---|---|---|---|---|
| File No | (Day End) Total Usage | - | (Day Start) Total Usage | = | Day Total Usage | /DE3 | = | Average Uses Per Hour |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

5. Interpreting the Data. The above information is useful for monitoring the usage of a particular program. Again, for FASTLINK, you are looking for files that are frequently used. In addition to high usage, you are looking for files that are used for short periods. To determine this, inspect the Display Perm-Open Files screen during the day as in paragraph 4e. If the file has high usage and it normally displays 0 or 1 active users, then this it is probably used for only short periods of time and is a good candidate for FASTLINK.

6. Cautions and Tradeoffs. Keeping a file open consumes a small amount of memory, even if the file is not being used. If many such files are permanently open the amount of memory that is "wasted" may become significant. The memory that is tied up could be used to improve other performance related tasks such as paging. Also, you will not be able to delete, patch, or rename any permanently opened files or dismount a volume that has permanently opened files on it.

7. Further Information. The Wang Utility manual (reference 7) contains an excellent discussion of FASTLINK and selecting files to keep permanently open.

8. Describe your agreement or disagreement with the following statement.

This information was new to me.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
| --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 |

9. Prior to receiving this questionnaire, how would you describe local involvement with FASTLINK analysis and optimization?

| None | Minimal | Moderate | Considerable | Extensive |
| --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 |

10. Comments. Any comments you have about this tutorial would be appreciated. In particular, we'd like to hear about disagreements you or others have with the information and ideas presented or success or problems you've had in this area of performance analysis and tuning.

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PART 13

## Data Collection Instructions and Tutorial

for

## Wang VS Page Pool Analysis

5 Sep 90

1. Purpose. The purpose of this document is to describe a method of analyzing the 'page pool' on a Wang VS computer to optimize performance. The method described should work on all USAF Civil Engineering Wang VS computers.

2. Completion Time. The total time to complete this exercise should be less than 30 minutes.

3. Background.

a. The Wang VS computer is a virtual memory system. This means that the total memory requirement of all users can exceed the actual physical memory installed. The system uses disk storage space to supplement the physical electronic memory (main memory). The central processor (CP) can only work directly with main memory. Each user is serviced in turn and given a share of the CP time. When this time is up, modified portions of the users program, must be moved from main memory to make room for another person's task. When the other user's processing window opens again, base program code and user modifiable data area must be read from disk back into memory. This process of transferring information back and forth between disk and memory is called 'paging'. When modified portions of a program are paged out to disk they are put into a temporary location. This temporary location can be a page pool or a paging file (12).

b. In this document the words 'individual page pool' refer to a single page pool on a disk. The words 'system page pool' refer to multiple, individual page pools as a collective system. The words 'page pool' refer to either concept. Two additional key terms are 'commitment' and 'physical usage' which describe two very different concepts and must not be confused. Commitment, sometimes called 'memory commitment' refers to the amount of modifiable data area assigned to a page pool. This modifiable data area represents potential (not actual) data. It is expressed as MB or as a percentage of the page pool capacity. If the maximum amount is assigned, the page pool is said to be fully committed. Physical usage (or utilization) refers to the amount of actual data stored in a page pool. This is expressed as MB or as a percentage of the page pool capacity.

c. If many users are working on the system, paging activity may be heavy. Under these conditions paging can have a great impact on system performance. Modified information is written to an individual page pool if one exists and if the pool is not already fully committed to other tasks. Otherwise, the modified data will be temporarily stored in paging files which are automatically created by the system. This is undesirable from a performance standpoint because these files may be located at many different points on the disk and are often fragmented. Paging files require more time to create and recover compared to their counterparts located in a paging pool. Ideally then, you should have page pool capacity to satisfy all users. The system administrator can control the size, number, and location of individual page pools (12).

d. Two important parameters in the page pool business are the page pool commitment ratio (CR) and the user modifiable data area (MDA). The commitment ratio determines how many users will be assigned to an individual page pool before it is fully committed. The CR is system wide and applies to all users. The default setting is 400% - one recommendation is to set it at 250% (14:5). The MDA is the maximum amount of modifiable data allowed per user in memory or in an individual page pool. The system default MDA is assigned by GENEDIT. Individual users can have different amounts assigned through SECURITY or VSSECURE. Both parameters can be controlled by the system administrator. The following equation shows the relationships of these variables.

Let
CR = commitment ratio (2 not 200%)
MDA = modifiable data area in MB
IPPS = individual page pool size in MB

Maximum users assigned to an individual page pool = IPPS*CR/MDA

If you have a 10 MB page pool, the commitment ratio is set at 400%, and the MDA for all users is 1 MB, then the maximum number of users that can be assigned to that page pool would be

10 * 4 / 1 = 40

e. If this was your only page pool, then running more than 40 tasks would require the use of page files instead of the page pool with a resulting deterioration in performance. Note that with 40 tasks the page pool is fully committed but will only be partially utilized (full of data) at any given time. This is because each task will generally only use a fraction of the 1 MB MDA allotted. In fact, with a commitment ratio of 4, each task can use at most 25% of their MDA (on the average) or the page pool will fill up. If a page pool becomes fully utilized (fills up) with data, the system may crash. Thus a page pool can be 100% committed but should never be allowed to become more than 75% utilized (to allow some margin for error). The computer provides warning errors if a page pool fills to near 100% physical usage; however, no messages are displayed if all individual page pools become fully committed.

f. From the above equation you can see that the number of tasks that can be assigned to page pool can be increased by (1) increasing the page pool size, (2) increasing the commitment ratio, or (3) decreasing the MDA for the tasks. See the cautions below for important information on changing these parameters.

g. The following additional parameters must be considered when developing your page pool configuration.

(1) Location on the disk. You want the page pools located near the busiest part of the disk. In general, the page pools should be placed on the outer portion of the disk near the VTOC. The location of a page pool is specified through DISKINIT. The location of an existing page pool can be found with the DISKMAP utility. (See Part 11, Disk Drive Analysis)

(2) Size of Page Pools. You want your page pools to be large enough to service your normal maximum loads but not so large that disk space is wasted. When first creating a page pool is wise to make it large and then monitor the usage with POOLSTAT. The size can later be reduced through the Relabel function of DISKINIT. Increasing the size later is difficult.

(3) Location among disks. Paging accounts for a great deal of I/O activity to and from the disks that are enabled for paging. In general you will want to enable several disks for paging and, to a lesser degree of importance, will want them distributed among the Input Output Processors (IOPs). The decision on number and placement of page pools can best be made with a complete evaluation of I/O activity on the system. (See Part 14, Disk I/O Bottleneck Detection).

h. Paging files are stored in library @SYSPAGE. Page pools are in library @SYSPOOL in file @POOL@.

4. Data Collection Instructions. Follow these directions to collect the data we need.

a. Select a day for collecting the data. The day you pick should be a typical duty day with an average amount of computer activity expected. Data will be collected once at approximately 1300.

b. Obtain your default MDA and page pool CR.

(To obtain the CR, go to the Operator's Console and select System Options (PF14) then Set System Parameters (PF4). To find the default MDA, go to the Operator's Console and select Non-Interactive tasks, then Initiator Control (PF11), and finally Create New Initiator (PF7). The value that appears is the default MDA. Exit this screen without creating the task. (13) (The default MDA can also be found by examining your configuration file using GENEDIT.)

Default MDA: __________ MB CR: _____%

c. Run the POOLSTAT utility near 1300L.

d. Fill in the following table for each of your individual page pools.

Time: ________L

Volume: __________

Page Pool Size (Capacity): __________ MB

Current usage: ________ MB ____%

Peak usage: ________ MB ____%

Memory commitment: ________ MB ____%

User count: ______ tasks assigned

Ref rate (Immed): ________ /sec

Ref rate (20% decay): ________ /sec

Volume: __________

Page Pool Size (Capacity): __________ MB

Current usage: ________ MB ____%

Peak usage: ________ MB ____%

Memory commitment: ________ MB ____%

User count: ______ tasks assigned

Ref rate (Immed): ________ /sec

Ref rate (20% decay): ________ /sec

Volume: __________

Page Pool Size (Capacity): __________ MB

Current usage: ________ MB ____%

Peak usage: ________ MB ____%

Memory commitment: ________ MB ____%

User count: ______ tasks assigned

Ref rate (Immed): ________ /sec

Ref rate (20% decay): ________ /sec

Volume: __________

Page Pool Size (Capacity): __________ MB

Current usage: ________ MB ____%

Peak usage: ________ MB ____%

Memory commitment: ________ MB ____%

User count: ______ tasks assigned

Ref rate (Immed): ________ /sec

Ref rate (20% decay): ________ /sec

Volume: __________

Page Pool Size (Capacity): __________ MB

Current usage: ________ MB ____%

Peak usage: ________ MB ____%

Memory commitment: ________ MB ____%

User count: ______ tasks assigned

Ref rate (Immed): ________ /sec

Ref rate (20% decay): ________ /sec

Volume: __________

Page Pool Size (Capacity): __________ MB

Current usage: ________ MB ____%

Peak usage: ________ MB ____%

Memory commitment: ________ MB ____%

User count: ______ tasks assigned

Ref rate (Immed): ________ /sec

Ref rate (20% decay): ________ /sec

e. Now figure the total size of your system page pool by adding up the sizes of the individual page pools:

System page pool size: ________ MB

f. Run program FILEDISP and search for libraries @SYSPAGE. Count the number of volumes with this library:

Volumes with @SYSPAGE: _______

List the number of files in each such library.

_____ files _____ files ____ files ____ files

If your page pools are adequate, all numbers will be 0.

5. Interpreting the Data. The above one time analysis is not sufficient to make decisions about your system page pool. Page pool statistics should be monitored over a period of at least a week and during peak load periods before considering changes.

a. If you have none or one individual page pool you should consider creating more after examining your I/O bottlenecks.

b. If the peak physical usage figures are **always** less than 50% then you might consider increasing your CR. This would allow more tasks to be assigned to the system page pool. This would only be an advantage if your page pool (system wide) is often fully committed (100%) (and as a result you are getting many paging files - or if you wish to reduce the size of the pool and it is often close to being fully committed (see paragraphs c and d below). See the cautions below.

c. If the memory commitment percentages are normally less than your CR, by an amount that would allow more assigned tasks, then you normally

do not have enough tasks running to fully commit the existing pool space. You may want to reduce the size of your page pool to free up additional disk space if the peak physical usages are also nearly always less than 50%. Use the following to determine if additional tasks could be assigned:

Let: IPPS = individual page pool size in MB
PMC = peak memory commitment in MB
MDA = modifiable data area in MB
CR = commitment ratio (4 not 400%)

Then if:

$$IPPS*CR - PMC > MDA$$

then more tasks could be assigned to this page pool.

d. If the memory commitment percentages are normally close or equal to the CR, then the page pools are normally fully committed and therefore some tasks are probably forced to use paging files. Under these conditions, @SYSPAGE libraries should exist. You should consider increasing the size of your pool by increasing individual page pool sizes or by adding an additional one. Alternatively, you might consider increasing the CR or decreasing the MDA to allow more users to be assigned to the pools.

6. <u>Cautions and Tradeoffs</u>. The subject of page pools is complex. No changes should be made until you fully understand the concepts and implications.

a. "Changes to the page pool commitment ratio can have a significant impact on the system. The page pool commitment ratio is a sensitive tuning parameter and should not be modified without considering the effects of the change (8:8.4)"

b. Reducing the default MDA may result in situations where certain programs will not run. Before reducing either the default MDA or that for an individual user, be certain no programs require more than the amount allotted.

7. <u>Additional Information</u>. For more information consult your Wang Utilities Reference and the VS Media Transfer and Device Utilities Reference (12).

8. Describe your agreement or disagreement with the following statement.

This information was new to me.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

9. Prior to receiving this questionnaire, how would you describe local involvement with page pool analysis and optimization?

| None | Minimal | Moderate | Considerable | Extensive |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

10. Comments. Any comments you have about this tutorial would be appreciated. In particular, we'd like to hear about disagreements you or others have with the information or ideas presented or success or problems you've had in this area of performance analysis and tuning.

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PART 14

## Data Collection Instructions and Tutorial

for

## Disk I/O Bottleneck Detection

5 Sep 90

1. Purpose. The purpose of this document is to describe a method of analyzing disk I/O (input output) paths on a Wang VS computer to optimize performance. The method described should work on all USAF Civil Engineering Wang VS computers.

2. Completion Time. The total time to complete this exercise should be less than 1 hour 30 minutes.

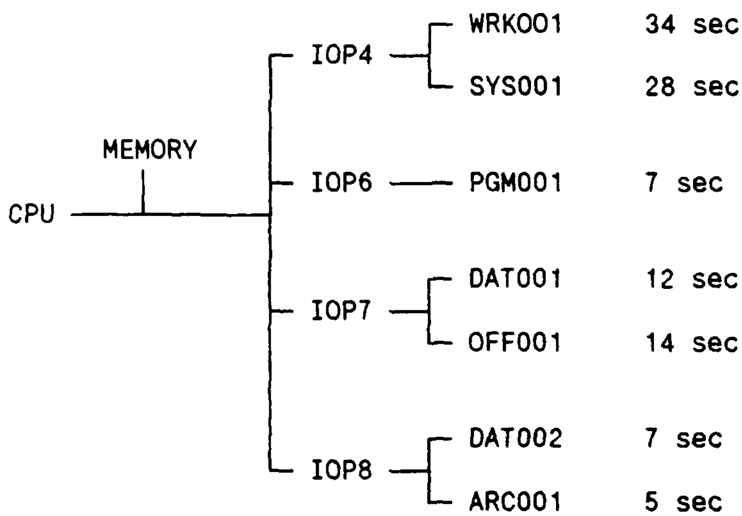
3. Background.

(1) An important part of performance tuning is the detection and elimination of bottlenecks in the computer system. One of the most important areas to at look are the I/O paths serving the disk drives. Under heavy use, queues (waiting lines) will develop to the disks and performance will suffer. The waiting lines are a normal part of doing business; however, all the queues should be spread out and of approximately the same size. You don't want a situation where some disks and IOPs are rarely used and the queues are short while others are severely overloaded and thus have large queues. Unfortunately the measurement of these queues is not possible with normally available tools.

(2) Program Description. A program, called IOBNDTCT, is under development to measure bottlenecks in the disk I/O channels. The program works as follows. It first calls the READVTOC VS subroutine to determine the configuration of your system - how many disk drives and where they are. Then it writes and erases a file several times to each disk and prints the time it starts on a disk and the time it finishes. The process time required for each disk gives a measurement of the extent of the queue on the path from the CPU to the disk drive.

(3) By comparing a one line diagram of the disk I/O channels and process times of the indicated program, you should be able to determine where bottlenecks exist. A sample diagram follows.

Sample disk I/O diagram:




In the above example, a problem likely exists with the drives connected with IOP4.

4. <u>Data Collection Instructions</u>. Follow these directions to collect the data we need.

a. The program must be sent to you over Wang Mail. Send a message to Capt Reno T. Lippold, AFIT/LSM, Wright-Patterson, LSM Student, asking for the program. A copy will be sent to you via Wang mail. (If you cannot communicate with Capt Lippold, then you will not be able to complete this part of the questionnaire.)

b. Select a day for collecting the data. The day you pick should be a typical duty day with an average amount of computer activity expected.

c. Draw a one line diagram, similar to the above, of the communications paths for your disk drives. This must include the IOPs (or IOCs) and the attached drives. Information on IOPs can be found through the Operator's Console, System Status, Control IOPs.

b. Run the bottleneck detection program once an hour between 1000 and 1300L. Record the times required to complete processing actions for each disk drive on the forms provided.

(1) Volume name: ________

Completion times:

| Time of Test | Processing Time |
|---|---|
| ________ | ________sec |
| ________ | ________sec |
| ________ | ________sec |
| ________ | ________sec |

Average the completion times by summing and dividing by four:

Average completion time: ________sec

(2) Volume name: ________

Completion times:

| Time of Test | Processing Time |
|---|---|
| ________ | ________sec |
| ________ | ________sec |
| ________ | ________sec |
| ________ | ________sec |

Average the completion times by summing and dividing by four:

Average completion time: ________sec

(3) Volume name: __________

| Completion times: | Time of Test | Processing Time |
|---|---|---|
| | __________ | __________sec |
| | __________ | __________sec |
| | __________ | __________sec |
| | __________ | __________sec |

Average the completion times by adding and dividing by four:

Average completion time: __________sec

(4) Volume name: __________

| Completion times: | Time of Test | Processing Time |
|---|---|---|
| | __________ | __________sec |
| | __________ | __________sec |
| | __________ | __________sec |
| | __________ | __________sec |

Average the completion times by adding and dividing by four:

Average completion time: __________sec

(5) Volume name: ________

| Completion times: | Time of Test | Processing Time |
| --- | --- | --- |
| | ________ | ________sec |
| | ________ | ________sec |
| | ________ | ________sec |
| | ________ | ________sec |

Average the completion times by adding and dividing by four:

Average completion time: ________sec

(6) Volume name: ________

| Completion times: | Time of Test | Processing Time |
| --- | --- | --- |
| | ________ | ________sec |
| | ________ | ________sec |
| | ________ | ________sec |
| | ________ | ________sec |

Average the completion times by summing and dividing by four:

Average completion time: ________sec

(7) Volume name: __________

| Completion times: | Time of Test | Processing Time |
|---|---|---|
| | __________ | __________sec |
| | __________ | __________sec |
| | __________ | __________sec |
| | __________ | __________sec |

Average the completion times by summing and dividing by four:

Average completion time: __________sec

(8) Volume name: __________

| Completion times: | Time of Test | Processing Time |
|---|---|---|
| | __________ | __________sec |
| | __________ | __________sec |
| | __________ | __________sec |
| | __________ | __________sec |

Average the completion times by summing and dividing by four:

Average completion time: __________sec

5. Interpreting the Data. Look for data paths that are consistently slower or faster than the average of the group. If a data path is considerable slower, there is probably too much traffic on it. Some experimentation will probably be required to even out the I/O queues. The detection program can identify a bottleneck in the path to a drive

but cannot exactly what is causing it - too much traffic to one disk or too much traffic through an IOP. The following options exist for reducing traffic to the disk or through the IOP.
(Large or imbalanced queues could be caused by disk inefficiencies as discussed in Parts 11 and 15 or excessive I/O activity as discussed in Parts 9 and 10. Work in these areas should be completed before making any major changes recommended in this Part.)

(1) If the objective is to reduce I/O traffic through an IOP:

- remove a disk from the busy IOP and place elsewhere

- exchange a device on the IOP with one that is less busy

(2) If the objective is to reduce I/O traffic to a specific disk drive or eliminate a bottleneck caused by an over worked disk:

- relocate active libraries to other drives

- deactivate the disk for paging, spooling (print files), or work files

- replace the drive with a faster unit

6. Cautions and Tradeoffs. Make sure no one is using files in a library before moving it. The results should be monitored before moving additional libraries (13). Removing disks between IOPs requires a Wang service call and a duty time system outage of several hours.

7. Describe your agreement or disagreement with the following statement.

This information was new to me.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

8. Prior to receiving this questionnaire, how would you describe local involvement with disk I/O bottleneck detection and correction?

None  Minimal  Moderate  Considerable  Extensive

9. Comments. Any comments you have about this tutorial would be appreciated. In particular, we'd like to hear about disagreements you or others have with the information and ideas presented or success or problems you've had in this area of performance analysis and tuning.

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PART 15

# Data Collection Instructions and Tutorial

for

# File Packing Factors and Compression

5 Sep 90

1. Purpose. The purpose of this document is to describe a method of using a files's 'packing factor' and compression status on a Wang VS computer to optimize performance. The method described should work on all USAF Civil Engineering Wang VS computers.

2. Completion Time. The total time to complete this exercise should be less than 10 minutes.

3. Background.

a. There are many different ways to store a file on disk. A popular method with large files is to store them compressed and with a 100 percent packing factor. In this mode all blank fields in each record are reduced and as many records as possible are stored into a block of disk storage space. The file takes up the least amount of disk space and provides very fast access - initially.

b. Unfortunately, this method may cause performance problems as the file is updated. If a record is added in the middle of the file (based on the primary key) or if blank fields are filled in, there will be no place to put this information. The block will split and in many cases the file will fragment. Block splits and file fragmentation complicate indexes resulting in slower access and update operations (see Part 11). Additionally, because of the way the system allocates additional extents, the amount of disk space allocated to the file will grow.

c. A better method may be to store the file as compressed but with data packing factor less than 100% - perhaps 85%. This will provide some room for expansion for filling in fields and reduce the rate of fragmentation. Using this method will require more disk space initially. Another alternative would be to store the disk as uncompressed with 100% packing factor. This would leave space for all the blank fields. If many fields are never used, this could waste disk space (2, 11:9.1).

d. The packing factor or compression of a file can be set during a copy operation or when the file is initially allocated. The setting stays with the file unless changed later (2). Two packing factors must be entered. One is for the data (DPACK) and one is for the indexes (IPACK). Since you anticipate less changes with the indexes than the

data, the packing factor for the indexes can be higher (example: 95% if the data packing factor were 85%) (11).

e. Eventually any file may develop block splits and become fragmented. COPY with REORG will fix the block splits and reestablish the growth space allocated according to the packing factor (and delete records marked for deletion).

4. Data Collection Instructions. Follow these directions to collect the data we need.

a. Start a copy operation on each of the files listed below. Open the file in the "Shared" mode. The second screen to appear (options screen) will have the current value of the packing factors listed. Abort the copy operation after collecting the data (at the third screen) (13).

b. Go to the command processor and select Manage Files and Libraries (PF5). Collect information for the following data files on compression and extents.

| File Name | In Library | Data Packing Factor | Extents | Compressed (yes/no) |
|---|---|---|---|---|
| MJOB | MJOBDATA | ______ | ______ | ______ |
| ERPR | ERXXDATA | ______ | ______ | ______ |
| EPRJ | E1XXDATA | ______ | ______ | ______ |
| MWOA | MWOXDATA | ______ | ______ | ______ |

5. Interpreting the Data. If the file is compressed and the packing factor is 100% then you are not taking advantage of possible performance gains for these and other files. If you typically have many extents in a data file, this may be a way to reduce this problem. If the file does not develop multiple extents, then it is not fragmenting, and therefore it is questionable whether any performance gains could made by changing either the packing factor or the compression.

6. Cautions and Tradeoffs. Using packing factors other than 100% or going from compressed to uncompressed will require more disk space. A shortage of free disk space can cause performance problems itself.

7. Describe your agreement or disagreement with the following statement.

This information was new to me.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

8. Prior to receiving this questionnaire, how would you describe local involvement with data file packing factor and compression analysis and optimization?

| None | Minimal | Moderate | Considerable | Extensive |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

9. Comments. Any comments you have about this tutorial would be appreciated. In particular, we'd like to hear about disagreements you or others have with the information or ideas presented or success or problems you've had in this area of performance analysis and tuning.

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## Appendix D. Questionnaire Data Summary

Abbreviations are listed at the end of the report.

DIRECTLY CODED VARIABLES

| DATA CODE | DESCRIPTION | DT | CM | PART | PARA |
|---|---|---|---|---|---|
| CASE | Base number | N | DF | 1 | 3 |
| MAJCOM | Major Command Number | N | DF | 1 | 5 |
| MILASGN | Military assigned | R | D | 1 | 6 |
| CIVASGN | Civilians assigned | R | D | 1 | 6 |
| TOTASGN | Total people assigned to the organization | R | D | 1 | 6 |
| NOCOMP | Number of computers (WANG VS only) | R | D | 2 | 1 |
| MODEL | Computer model (reported on) | N | DF | 2 | 3 |
| YEARS | Years the system has been operational | R | D | 2 | 1 |
| SYSMEM | Physical memory installed (MB) | R | D | 2 | 5 |
| DRIVES | Number of disk drives installed | R | D | 2 | 6 |
| LOCWS | Number of local work stations | R | D | 2 | 7 |
| REMWS | Number of remote work stations | R | D | 2 | 8 |
| PCWS | Number of PCs connected as work stations | R | D | 2 | 9 |
| TOTWS | Total number of work stations connected | R | D | 2 | 10 |
| USERS | Users assigned to the computer | R | D | 2 | 11 |
| WIMS | Does the system run WIMS? (Y/N) | N | D | 3 | 1 |
| CEMAS | Does the system run CEMAS? (Y/N) | N | D | 3 | 1 |
| PERFSW | Number of performance software packages used | I | DF | 3 | 2 |
| SP1C | Software package 1 cost ($) | R | DF | 3 | 2 |
| SP1IP | Software package 1 improvement in perf | I | DF | 3 | 2 |
| SP1V | Software package 1 value | I | DF | 3 | 2 |
| | "identical data for each package reported" | | | | |
| OS | Operating system installed | N | D | 3 | 3 |
| MAN | Manpower dedicated to WIMS mgmt (hrs/wk) | R | D | 4 | 3 |
| YRSEXP | Total years experience of the mgmt | R | D | 4 | 3 |
| TRAIN | Training level of management | I | DQ | 4 | 3 |
| ADTASK | Amount of admin work done during duty hours | I | DQ | 5 | 1/2 |
| CMPLN | How often are perf complaints received | I | D | 6 | 1 |
| UPOPSA | The user's perception of perf by the SA | I | D | 6 | 2 |
| SAPERA | The SSAs performance assessment | I | D | 6 | 3 |
| LIP | Local involvement with performance issues. | I | D | 6 | 4 |
| SPI | The system performance index (sec) | I | D | 7 | 4 |
| PKPI | Prior knowledge of performance indexes | I | D | 7 | 7A |
| VTPI | Value of this tool for perf measurement | I | D | 7 | 7B |

| | | | | | |
|---|---|---|---|---|---|
| LIPI | Local involvement with performance indexes | I | D | 7 | 8 |
| | | | | | |
| NOUS | Number of users surveyed | R | D | 8 | 4b |
| NORR | Number of replies received | R | D | 8 | 4b |
| USATA | How many felt very dissat about perf | I | D | 8 | 4b1 |
| USATB | How many felt dissat about performance | I | D | 8 | 4b1 |
| USATC | How many felt neutral about performance | I | D | 8 | 4b1 |
| USATD | How many felt satisfied about performance | I | D | 8 | 4b1 |
| USATE | How many felt very satisfied about perf | I | D | 8 | 4b1 |
| USATNA | How many did not answer the sat question | R | D | 8 | 4b1 |
| IMPA | How many felt perf was least important | I | D | 8 | 4b2 |
| IMPB | How many felt perf was of low importance | I | D | 8 | 4b2 |
| IMPC | How many felt perf was of medium importance | I | D | 8 | 4b2 |
| IMPD | How many felt perf was of high importance | I | D | 8 | 4b2 |
| IMPE | How many felt perf was of very high import | I | D | 8 | 4b2 |
| IMPNA | How many did not answer the importance quest | R | D | 8 | 4b2 |
| WAITA | How many waited less than 1 minute per day | R | D | 8 | 4b3 |
| WAITB | How many waited from 1 to 4 minutes per day | R | D | 8 | 4b3 |
| WAITC | How many waited from 4 to 8 minutes per day | R | D | 8 | 4b3 |
| WAITD | How many waited from 8 to 15 minutes per day | R | D | 8 | 4b3 |
| WAITE | How many waited from 15 to 25 min per day | R | D | 8 | 4b3 |
| WAITF | How many waited more than 25 minutes per day | R | D | 8 | 4b3 |
| WAITNA | How many did not answer the waiting question | ? | D | 8 | 4b3 |
| PKUSIA | Prior knowledge of user sat and impact anal | I | D | 8 | 7 |
| LIUSIA | Local involvement with user sat and impact | R | D | 8 | 8 |
| | | | | | |
| SBUFF | Number of Sharer buffers | R | D | 9 | 4b |
| SBUFFF | Are the Sharer buffers fixed? (Y/N) | N | D | 9 | 4b |
| SCBF | Are the Sharer control blocks fixed? (Y/N) | N | D | 9 | 4b |
| SHR | Sharer hit ratio | R | D | 9 | 4b(4) |
| SMR | Sharer miss rate | R | D | 9 | 4b(5) |
| PKSA | Prior knowledge of Sharer analysis | I | D | 9 | 7 |
| LISA | Local involvement with Sharer analysis | R | D | 9 | 8 |
| | | | | | |
| VCBUFF | Number of VTOC cache buffers. | R | D | 10 | 4b |
| VCHR | VTOC cache hit ratio | R | D | 10 | 4c(4) |
| VCMR | VTOC cache miss rate (misses per second) | R | D | 10 | 4c(5) |
| PKVCA | Prior knowledge of VTOC cache analysis | I | D | 10 | 7 |
| LIVCA | Local involvement with VTOC cache analysis | R | D | 10 | 8 |
| | | | | | |
| D1NAME | Name of disk 1 | N | D | 11 | 4c |
| D2NAME | Name of disk 2 | N | D | 11 | 4c |
| D3NAME | Name of disk 3 | N | D | 11 | 4c |
| D4NAME | Name of disk 4 | N | D | 11 | 4c |
| D5NAME | Name of disk 5 | N | D | 11 | 4c |
| D6NAME | Name of disk 6 | N | D | 11 | 4c |
| D7NAME | Name of disk 7 | N | D | 11 | 4c |
| D8NAME | Name of disk 8 | N | D | 11 | 4c |
| D1FEXNT | Number of free extents for disk 1 | R | D | 11 | 4a |
| D2FEXNT | Number of free extents for disk 2 | R | D | 11 | 4a |
| D3FEXNT | Number of free extents for disk 3 | R | D | 11 | 4a |
| D4FEXNT | Number of free extents for disk 4 | R | D | 11 | 4a |

| | | | | | |
|---|---|---|---|---|---|
| D5FEXNT | Number of free extents for disk 5 | R | D | 11 | 4a |
| D6FEXNT | Number of free extents for disk 6 | R | D | 11 | 4a |
| D7FEXNT | Number of free extents for disk 7 | R | D | 11 | 4a |
| D8FEXNT | Number of free extents for disk 8 | R | D | 11 | 4a |
| D1FTS | Fault tolerance setting for disk 1 | O | DE | 11 | 4c |
| D2FTS | Fault tolerance setting for disk 2 | O | DE | 11 | 4c |
| D3FTS | Fault tolerance setting for disk 3 | O | DE | 11 | 4c |
| D4FTS | Fault tolerance setting for disk 4 | O | DE | 11 | 4c |
| D5FTS | Fault tolerance setting for disk 5 | O | DE | 11 | 4c |
| D6FTS | Fault tolerance setting for disk 6 | O | DE | 11 | 4c |
| D7FTS | Fault tolerance setting for disk 7 | O | DE | 11 | 4c |
| D8FTS | Fault tolerance setting for disk 8 | O | DE | 11 | 4c |
| D1PF | Percent full for disk 1 | I | D | 11 | 4c |
| D2PF | Percent full for disk 2 | I | D | 11 | 4c |
| D3PF | Percent full for disk 3 | I | D | 11 | 4c |
| D4PF | Percent full for disk 4 | I | D | 11 | 4c |
| D5PF | Percent full for disk 5 | I | D | 11 | 4c |
| D6PF | Percent full for disk 6 | I | D | 11 | 4c |
| D7PF | Percent full for disk 7 | I | D | 11 | 4c |
| D8PF | Percent full for disk 8 | I | D | 11 | 4c |
| UPS | Does the system have a UPS? (Y/N) | N | D | 11 | 4d |
| UVERR | Unreliable VTOC errors | R | D | 11 | 4e |
| UVERRP | Period for the VTOC errors (months) | R | D | 11 | 4e |
| UVERRV | Unreliable VTOC errors verified | R | D | 11 | 4f |
| UVERRC | VTOC errors with data loss and crash prot | R | D | 11 | 4g |
| UVERRN | VTOC errors with data loss and no prot | R | D | 11 | 4h |
| UVERRM | VTOC errors with data loss and media prot | R | D | 11 | 4i |
| LIWFC | Local involvement with file collocation | N | DE | 11 | 4j |
| PKDDA | Prior knowledge of disk drive analysis | I | D | 11 | 7 |
| LIDDA | Local involvement with disk drive analysis | R | D | 11 | 8 |
| | | | | | |
| FLU | Fastlink utilization (Y/N) | N | D | 12 | 4a |
| NFLFO | Number of Fastlink files open | R | D | 12 | 4d |
| F1NUM | Number of the permanently open file 1 | N | DE | 12 | 4d |
| F1MMAU | File 1 midmorning active users | R | D | 12 | 4e |
| F1MAAU | File 1 midafternoon active users | R | D | 12 | 4e |
| F1AU | File 1 average usage (uses per hour) | R | D | 12 | 4f |
| | "identical data for each file reported" | | | | |
| PKF | Prior knowledge of Fastlink | I | D | 12 | 8 |
| LIFA | Local involvement with Fastlink analysis | R | D | 12 | 9 |
| | | | | | |
| MDA | The default modifiable data area | R | D | 13 | 4b |
| CR | The system commitment ratio | R | D | 13 | 4b |
| PP | Number of page pools | R | D | 13 | 4d |
| PP1S | Page pool 1 size (MB) | R | D | 13 | 4d |
| PP1PU | Page pool 1 peak usage (MB) | R | D | 13 | 4d |
| PP1MC | Page pool 1 memory commitment (%) | R | D | 13 | 4d |
| | "Identical data for each page pool" | | | | |
| SPPS | System page pool size (MB) | R | D | 13 | 4d |
| ASPL | Number of @SYSPAGE libraries | R | D | 13 | 4f |
| PKPPA | Prior knowledge of page pool analysis | I | D | 13 | 8 |
| LIPPA | Local involvement with page pool analysis | R | D | 13 | 9 |

| | | | | | |
|---|---|---|---|---|---|
| D1IOBNT | Disk 1 I/O bottleneck time (sec) | R | D | 14 | 4b |
| D2IOBNT | Disk 2 I/O bottleneck time (sec) | R | D | 14 | 4b |
| D3IOBNT | Disk 3 I/O bottleneck time (sec) | R | D | 14 | 4b |
| D4IOBNT | Disk 4 I/O bottleneck time (sec) | R | D | 14 | 4b |
| D5IOBNT | Disk 5 I/O bottleneck time (sec) | R | D | 14 | 4b |
| D6IOBNT | Disk 6 I/O bottleneck time (sec) | R | D | 14 | 4b |
| D7IOBNT | Disk 7 I/O bottleneck time (sec) | R | D | 14 | 4b |
| D8IOBNT | Disk 8 I/O bottleneck time (sec) | R | D | 14 | 4b |
| PKIOBN | Prior knowledge of I/O bottleneck info | I | D | 14 | 7 |
| LIIOBNA | Local involvement with I/O bottleneck anal | R | D | 14 | 8 |
| PFJOB | The packing factor for the job order file | I | D | 15 | 4b1 |
| PFEPRJ | The packing factor for engineering projects | I | D | 15 | 4b3 |
| PFRPR | The packing factor for real property data | I | D | 15 | 4b2 |
| PFWO | The packing factors for work orders | I | D | 15 | 4b4 |
| EXTJOB | Extents for the job order file | I | D | 15 | 4b1 |
| EXTRPR | Extents for the real property file | I | D | 15 | 4b2 |
| EXTEPRJ | Extents for the engineering projects file | I | D | 15 | 4b3 |
| EXTWO | Extents for the work order file | I | D | 15 | 4b4 |
| COMJOB | Compression for job orders | O | D | 15 | 4b1 |
| COMRPR | Compression for the real property file | O | D | 15 | 4b2 |
| COMEPRJ | Compression for engineering projects file | O | D | 15 | 4b3 |
| COMWO | Compression for work order file | O | D | 15 | 4b4 |
| PKPFC | Prior knowledge of packing factors | I | D | 15 | 7 |
| LIFPFC | Local involvement with packing factors | R | D | 15 | 8 |

INDIRECTLY CODED VARIABLES

| | | | | |
|---|---|---|---|---|
| MUSAT | The mean of the satisfaction level | I | IF | |
| MIMP | The mean of importance placed on performance | I | IF | |
| MWAIT | The mean waiting period | R | IF | |
| CSPI | Converted PI | I | IF | |
| CCMPLN | Converted CCMPLN | I | IF | |
| MPI | Master performance index | I | IF | Multi |
| MDIOBNT | The mean I/O time for a base | R | IF | |

ABBREVIATIONS

HEADINGS:

DL - data level
- N - nominal
- O - ordinal
- I - interval
- R - ratio

CM - coding method

- D - direct (data comes from inspection of the questionnaire)
- DE - direct with explanation
- DQ - direct with qualitative judgement
- IF - indirect (computed by formula from the direct data)

PARA - paragraph

OTHER:

admin - administrative
anal - analysis
dissat - dissatisfied
hrs - hours
info - information
MB - megabytes
mgmt - management
perf - performance
quest - question
sat - satisfaction
sec - seconds
wk - week
Y/N - yes or no

## Appendix E: Data Coding Methods and Conversions

Data Coding Methods. The statistical package used to analyze the data accepts only numbers so all nominal and ordinal data must be assigned a number. The following section provides a cross reference for this coding. The reader should realize that the data remains at its own class - nominal or ordinal despite being assigned a number.

Yes and No Answers. Yes = 1 No = 0

| Base Name | CASE |
|---|---|
| Columbus AFB MS | 1 |
| England AFB LA | 2 |
| McChord AFB WA | 3 |
| Castle AFB CA | 4 |
| Lackland AFB TX | 5 |
| Moody AFB GA | 6 |
| Cheyenne Mtn Cmplx CO | 7 |
| Homestead AFB FL | 8 |
| Hill AFB UT | 9 |
| Sheppard AFB TX | 10 |
| Kirtland AFB NM | 11 |
| Lowry AFB CO | 12 |
| Maxwell AFB AL | 13 |
| Anonymous | 14 |
| Anonymous | 15 |
| Norton AFB CA | 16 |
| McClellan AFB CA | 17 |
| Hurlburt Field FL | 18 |

| | |
|---|---|
| Robins AFB GA | 19 |
| Wurthsmith AFB MI | 20 |
| Luke AFB AZ | 21 |
| Anonymous | 22 |
| Laughlin AFB TX | 23 |
| USAF Academy | 24 |
| Eaker AFB AR | 25 |
| McConnel AFB KS | 26 |
| Peterson AFB CO | 27 |
| Whiteman AFB MO | 28 |
| Nellis AFB NV | 29 |
| Dover AFB DE | 30 |
| Mountain Home AFB ID | 31 |
| Keelser AFB MS | 32 |
| Ellsworth AFB SD | 33 |
| Holloman AFB NM | 34 |
| Davis Montham AZ | 35 |
| Bergstrom AFB TX | 36 |
| Anonymous | 37 |
| Anonymous | 38 |
| Anonymous | 39 |
| Patrick AFB FL | 40 |
| Fairchild AFB FL | 41 |
| Cannon AFB NM | 42 |
| KI Sawyer AFB MI | 43 |

| MAJCOM Name | Coding Number (MAJCOM) |
| --- | --- |
| SAC | 1 |
| MAC | 2 |
| TAC | 3 |
| ATC | 4 |
| AFSC | 5 |
| AU | 6 |
| AFLC | 7 |
| SPACECOM | 8 |

| Computer Model | Coding Number (MODEL) |
| --- | --- |
| VS 100 | 1 |
| VS 7310 | 2 |
| VS 5000 | 3 |
| VS 85 | 4 |

| Software Package Name | Coding Number (SP_N) |
| --- | --- |
| System Minder | 1 |
| Space Saver | 2 |
| WORM | 3 |
| SAM | 4 |
| VS Space | 5 |

| Operating System | Number (OS) |
|---|---|
| 7.19 | 1 |
| 7.21 | 2 |
| 7.3 | 3 |
| 7.20 | 4 |

| Fault Tolerance Setting | Coding Number (D FTS) |
|---|---|
| No Setting | 1 |
| Crash Tolerant | 2 |
| Media Tolerant | 3 |

| File Collocation Involvement | Coding Number (LIWFC) |
|---|---|
| Yes | 1 |
| No | 0 |
| Not Sure | 2 |

| Fastlink File Name | Coding Number (F_NUM) |
|---|---|
| INQUIRY | 1 |
| SORT | 2 |
| DISPLAY | 3 |
| REPORT | 4 |
| COPY | 5 |
| IVARUREAD | 6 |
| IVARVALS | 7 |
| WG3PRINT | 8 |
| @SHARER@ | 9 |

| | |
|---|---|
| @OPER@ | 10 |
| WSRSTR | 11 |
| @ATTACH@ | 12 |
| @PROC@ | 13 |
| @SYSINIT | 14 |
| IVAR4PRT | 15 |
| MWDAUD | 16 |
| WG3CANDM | 17 |
| MBMIUD | 18 |
| WPEMUSSL | 19 |
| MJOBUD | 20 |
| WC1PASS2 | 21 |
| WC1PASS1 | 22 |
| COBOL | 23 |
| EDITOR | 24 |
| WPDISP | 25 |
| COPYWP | 26 |
| @OPER@ | 27 |

ADTASK. An interval level description of the amount of administrative work done during duty hours. This is work that could be performed after duty hours to reduce the day time computer workload. The data in Part 5 will be examined and the following scale will be used to provide a numeric score for the system.

| None | Minimal | Moderate | Most | Nearly All |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

CCMPLN. Converted CMPLN. CMPLN is an interval variable with higher numbers representing poorer performance. It is converted so that higher numbers represent better performance in the range from 1 to 5.

CCMPLN = 6 - CMPLN

CSPI. Converted System Performance Index (SPI). SPI is shifted, scaled and converted as follows to provide an index increasing with better performance in the range from 1 to 5.

SSPI = SPI - SPImin (shifts the data so it begins at 0)

SCSSPI = (SSPI*4/SSPImax) (puts the data on a 0 to 4 scale)

CSPI = 5 - SCSSPI (inverts the values so the increasing numbers correspond to better performance and puts the data on a 1 - 5 scale)

Where:

SPI is the system performance index for the system under examination.
SSPI is the data shifted to start at 0.
SSPImax is the maximum value of SSPI for the entire sample.
SPImin is the minimum value of SPI for the entire sample.

Note that these numbers are in the same proportions only over a range of 1 to 5 with 1 being the worst performer of the sample and 5 the best.

MDIOBNT. The mean of the I/O bottleneck times (DxIOBNT) for a base.

MIMP. The mean of the IMP variables weighted by its score value.

MIMP = (IMPA + 2*IMPB + 3*IMPC + 4*IMPD + 5*IMPE)/DENOM

DENOM = IMPA + IMPB + IMPC + IMPE + IMPD

MPI. Master Performance Index (PI). MPI provides an interval level description of the performance of a particular computer system. It is derived from 5 data elements collected on system performance and has the following functional relationship.

MPI = f(CSPI, CCMPLN, UPOPSA, SAPERA, MUSAT)

Each of the above independent variable range from 1 to 5 and are interval. They will be combined using weighting factors. The performance index is the most objective measurement and will therefore be give a large percentage of the weighting. The others are about equal in value with user satisfaction (MUSAT) given twice the weight of the other subjective factors. The conversion formula is

MPI = (.5*CSPIO + .1*CCMPLNO + .1*UPOPSAO + .1*SAPERAO +
.2*MUSATO) / NV

NV is a normalizing constant which equals the sum of the weighting factors for the variable that have values. For example, if values exist for all variables except MUSAT then NV would be .8. This provides a range of MPI again from 1 to 5 with higher numbers corresponding to better performance.

MUSAT. The mean of the USAT variables. This will be a simple mean of the data obtained from USAT A - E.

MUSAT = (USATA + 2*USATB + 3*USATC + 4*USATD + 5*USATE) / DENOM

DENOM = (USAT + USATB + USATC + USATD + USATE)

PERFSW. This is an interval level variable reflecting the use of performance tuning and improvement software on the system. The variable will receive a numeric value based on the number of packages run on the system.

TRAIN. An interval level description of the formal training level of the computer operations and management personnel. The data in Part 4 will be examined and a numeric score will be assigned as follows.

| None | Minimal | Moderate | Considerable | Extensive |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

MWAIT. The mean of the WAIT variables. The average waiting period for the base group. Determined by the following formula.

WAITAV = (WAITA*30 + WAITB*150 + WAITC*360 + WAITD*690 + WAITE*1200 + WAITF*1800) / DENOM

DENOM = (WAITA + WAITB + WAITC + WAITD + WAITE + WAITF)

The numbers represent the medium number of seconds represented by each answer. For example, a C answer means the wait is between 4 and 8 minutes. 6 is midway between and is 360 seconds. Thus using these weighting factors, the above formula is determining the mean response.

## Appendix F: Raw Data

The data were stored in three data bases - two with 43 cases and one with 8 cases. Each data base is indicated. The first group is data base 1. M signifies missing information.

| CASE | MAJCOM | MILASGN | CIVASGN | TOTASGN | NOCOMP | MODEL | YEARS | SYSMEM |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.00 | 165.00 | 135.00 | 300.00 | 1.00 | 1.00 | 2.00 | 8.00 |
| 2 | 3.00 | 161.00 | 94.00 | 255.00 | 1.00 | 1.00 | 1.00 | 12.30 |
| 3 | 2.00 | 197.00 | 180.00 | 377.00 | 1.00 | 1.00 | 3.00 | 8.00 |
| 4 | 1.00 | 201.00 | 133.00 | 334.00 | 1.00 | 1.00 | 3.50 | 8.20 |
| 5 | 4.00 | 86.00 | 587.00 | 673.00 | 4.00 | 2.00 | 0.75 | 24.50 |
| 6 | M | 120.00 | 105.00 | 225.00 | 1.00 | 1.00 | 3.50 | 16.00 |
| 7 | 8.00 | 164.00 | 52.00 | 216.00 | 2.00 | 1.00 | 4.00 | 8.00 |
| 8 | 3.00 | 296.00 | 193.00 | 489.00 | 2.00 | 1.00 | 3.50 | 16.00 |
| 9 | 7.00 | 387.00 | 563.00 | 950.00 | 5.00 | 1.00 | 3.00 | 8.00 |
| 10 | 4.00 | 228.00 | 183.00 | 411.00 | 1.00 | 1.00 | 2.50 | 8.00 |
| 11 | 2.00 | 219.00 | 334.00 | 553.00 | 1.00 | 1.00 | 2.00 | 8.00 |
| 12 | 4.00 | 200.00 | 185.00 | 385.00 | 1.00 | 1.00 | 2.50 | M |
| 13 | 6.00 | 199.00 | 220.00 | 419.00 | 3.00 | 1.00 | 4.00 | 16.00 |
| 14 | 1.00 | 264.00 | 135.00 | 399.00 | 1.00 | 1.00 | 3.50 | 8.00 |
| 15 | 3.00 | 191.00 | 135.00 | 326.00 | 1.00 | 1.00 | 2.00 | 8.20 |
| 16 | 2.00 | 212.00 | 207.00 | 419.00 | 1.00 | 1.00 | 3.00 | 8.00 |
| 17 | 7.00 | 301.00 | 458.00 | 759.00 | 2.00 | 1.00 | 3.50 | 8.20 |
| 18 | 2.00 | 221.00 | 105.00 | 326.00 | 1.00 | 1.00 | 2.00 | 8.00 |
| 19 | 7.00 | M | M | M | 2.00 | M | M | M |
| 20 | 1.00 | 247.00 | 169.00 | 416.00 | 1.00 | 1.00 | 3.50 | 8.00 |
| 21 | 3.00 | 228.00 | 150.00 | 378.00 | 1.00 | 1.00 | 4.00 | 16.00 |
| 22 | M | M | M | M | 2.00 | 1.00 | 3.00 | 6.00 |
| 23 | 4.00 | 143.00 | 119.00 | 262.00 | 1.00 | 1.00 | 2.00 | 8.20 |
| 24 | M | 117.00 | 384.00 | 561.00 | 1.00 | 1.00 | 4.00 | 16.40 |
| 25 | 1.00 | 190.00 | 120.00 | 310.00 | 1.00 | 1.00 | 3.00 | 9.20 |
| 26 | 1.00 | 183.00 | 167.00 | 350.00 | 1.00 | 1.00 | 4.00 | 8.00 |
| 27 | 8.00 | 179.00 | 106.00 | 285.00 | 1.00 | 1.00 | 3.00 | 8.00 |
| 28 | 1.00 | 273.00 | 157.00 | 430.00 | 2.00 | 1.00 | 3.50 | 8.00 |
| 29 | 3.00 | 292.00 | 236.00 | 529.00 | 3.00 | 1.00 | 3.00 | 16.40 |
| 30 | 2.00 | 212.00 | 255.00 | 465.00 | 1.00 | 1.00 | 3.00 | 8.00 |
| 31 | 3.00 | 216.00 | 189.00 | 405.00 | 2.00 | 1.00 | 2.50 | 16.00 |
| 32 | 4.00 | 216.00 | 261.00 | 477.00 | 1.00 | 1.00 | 3.50 | 8.00 |
| 33 | 1.00 | M | M | M | 1.00 | 1.00 | 3.00 | 16.40 |
| 34 | 3.00 | 305.00 | 359.00 | 664.00 | 1.00 | 1.00 | 2.00 | 16.00 |
| 35 | 3.00 | 200.00 | 205.00 | 405.00 | 2.00 | 1.00 | 3.50 | 16.00 |
| 36 | 3.00 | 175.00 | 135.00 | 310.00 | 1.00 | 1.00 | 3.00 | 16.00 |
| 37 | 2.00 | 222.00 | 168.00 | 390.00 | 1.00 | 1.00 | 4.00 | 8.20 |
| 38 | 4.00 | M | M | M | 3.00 | 1.00 | 1.00 | 8.00 |
| 39 | 3.00 | M | M | M | 2.00 | 1.00 | 3.00 | M |
| 40 | 5.00 | 207.00 | 243.00 | 450.00 | 4.00 | 1.00 | 2.75 | 16.00 |
| 41 | 1.00 | 235.00 | 193.00 | 248.00 | 1.00 | 1.00 | 3.50 | 16.00 |
| 42 | 3.00 | 218.00 | 145.00 | 363.00 | 1.00 | 1.00 | 3.00 | 12.00 |
| 43 | 1.00 | M | M | M | 1.00 | 1.00 | 3.00 | 8.00 |

| CASE | DRIVES | LOCWS | REMWS | PCWS | TOTWS | USERS | WIMS | CEMAS |
|---|---|---|---|---|---|---|---|---|
| 1 | 6.00 | 75.00 | 16.00 | 16.00 | 107.00 | 150.00 | 1.00 | 1.00 |
| 2 | 7.00 | 57.00 | 28.00 | 21.00 | 106.00 | 234.00 | 1.00 | 1.00 |
| 3 | 6.00 | 87.00 | 6.00 | 25.00 | 112.00 | 285.00 | 1.00 | 1.00 |
| 4 | 7.00 | 78.00 | 16.00 | 15.00 | 109.00 | 150.00 | 1.00 | 1.00 |
| 5 | 7.00 | 154.00 | 51.00 | 17.00 | 222.00 | 368.00 | 1.00 | 1.00 |
| 6 | 7.00 | 75.00 | 15.00 | 35.00 | 125.00 | 231.00 | 1.00 | 1.00 |
| 7 | 6.00 | 38.00 | 24.00 | 22.00 | 84.00 | 231.00 | 1.00 | 0.00 |
| 8 | 6.00 | 87.00 | 15.00 | 17.00 | 119.00 | 299.00 | 1.00 | 1.00 |
| 9 | 6.00 | 93.00 | 19.00 | 11.00 | 122.00 | 199.00 | 1.00 | 1.00 |
| 10 | 8.00 | 83.00 | 19.00 | 20.00 | 122.00 | 260.00 | 1.00 | 1.00 |
| 11 | 5.00 | 155.00 | 11.00 | 7.00 | 173.00 | 370.00 | 1.00 | 1.00 |
| 12 | 6.00 | 88.00 | 1.00 | 24.00 | 112.00 | 320.00 | 1.00 | 1.00 |
| 13 | 8.00 | 89.00 | 13.00 | 24.00 | 118.00 | 300.00 | 1.00 | 1.00 |
| 14 | 6.00 | 105.00 | 22.00 | 0.00 | 127.00 | 258.00 | 1.00 | 1.00 |
| 15 | 6.00 | 82.00 | 15.00 | 30.00 | 127.00 | 309.00 | 1.00 | 1.00 |
| 16 | 6.00 | 90.00 | 13.00 | 31.00 | 134.00 | 290.00 | 1.00 | 1.00 |
| 17 | 5.00 | 101.00 | 31.00 | 11.00 | 143.00 | 301.00 | 1.00 | 1.00 |
| 18 | 6.00 | 70.00 | 17.00 | 12.00 | 99.00 | 120.00 | 1.00 | 1.00 |
| 19 | 6.00 | M | M | M | M | M | M | M |
| 20 | 6.00 | 83.00 | 17.00 | 15.00 | 115.00 | 275.00 | 1.00 | 1.00 |
| 21 | 10.00 | 100.00 | 10.00 | 16.00 | 126.00 | 305.00 | 1.00 | 1.00 |
| 22 | 9.00 | 163.00 | 24.00 | 0.00 | 187.00 | 250.00 | 1.00 | 1.00 |
| 23 | 6.00 | 57.00 | 29.00 | 10.00 | 96.00 | 182.00 | 1.00 | 1.00 |
| 24 | 8.00 | 71.00 | 40.00 | 17.00 | 128.00 | 392.00 | 1.00 | 1.00 |
| 25 | 6.00 | 80.00 | 4.00 | 17.00 | 101.00 | 250.00 | 1.00 | 1.00 |
| 26 | 8.00 | 90.00 | 14.00 | 11.00 | 115.00 | 215.00 | 1.00 | 1.00 |
| 27 | 8.00 | 93.00 | 18.00 | 23.00 | 134.00 | M | 1.00 | 1.00 |
| 28 | 6.00 | 91.00 | 15.00 | 16.00 | 122.00 | M | 1.00 | 1.00 |
| 29 | 9.00 | 108.00 | 8.00 | 11.00 | 127.00 | 329.00 | 1.00 | 1.00 |
| 30 | 6.00 | 71.00 | 35.00 | 21.00 | 127.00 | 470.00 | 1.00 | 1.00 |
| 31 | 6.00 | 67.00 | 11.00 | 11.00 | 89.00 | 230.00 | 1.00 | 1.00 |
| 32 | 6.00 | 90.00 | 18.00 | 20.00 | 128.00 | 310.00 | 1.00 | 1.00 |
| 33 | 8.00 | 105.00 | 10.00 | 13.00 | 128.00 | 425.00 | 1.00 | 1.00 |
| 34 | 10.00 | 103.00 | 14.00 | 12.00 | 129.00 | 313.00 | 1.00 | 1.00 |
| 35 | 9.00 | 91.00 | 8.00 | 19.00 | 118.00 | 320.00 | 1.00 | 1.00 |
| 36 | 7.00 | 89.00 | 10.00 | 23.00 | 129.00 | 289.00 | 1.00 | 1.00 |
| 37 | 6.00 | 79.00 | 14.00 | 17.00 | 110.00 | 220.00 | 1.00 | 1.00 |
| 38 | 6.00 | 82.00 | 12.00 | 41.00 | 135.00 | 300.00 | 1.00 | 1.00 |
| 39 | 9.00 | 86.00 | 15.00 | 16.00 | 117.00 | 309.00 | 1.00 | 1.00 |
| 40 | 6.00 | 82.00 | 33.00 | 13.00 | 128.00 | 247.00 | 1.00 | 1.00 |
| 41 | 6.00 | 108.00 | 12.00 | 8.00 | 128.00 | 330.00 | 1.00 | 1.00 |
| 42 | 7.00 | 78.00 | 9.00 | 30.00 | 117.00 | 300.00 | 1.00 | 1.00 |
| 43 | 6.00 | 80.00 | 12.00 | 16.00 | 108.00 | 237.00 | 1.00 | 1.00 |

| CASE | PERFWS | OS | MAN | YRSEXP | TRAIN | ADTASK | CMPLN | UPOPSA |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 1.00 | 152.00 | 4.00 | 2.50 | 2.00 | 2.00 | 3.00 |
| 2 | M | 2.00 | 120.00 | 6.00 | 3.50 | 3.50 | 4.00 | 2.00 |
| 3 | 1.00 | M | 100.00 | 3.00 | M | 4.50 | 3.00 | 2.00 |
| 4 | 1.00 | M | 120.00 | 1.50 | 1.00 | 3.30 | 3.00 | 5.00 |
| 5 | 1.00 | 3.00 | 145.00 | 9.00 | 1.00 | 3.00 | 5.00 | 3.00 |
| 6 | 0.00 | M | 153.00 | 13.00 | 3.00 | 2.50 | 2.00 | 5.00 |
| 7 | 0.00 | M | 115.00 | 5.30 | 3.50 | 2.50 | 3.00 | 3.00 |
| 8 | 2.00 | M | 80.00 | 2.50 | 2.50 | 3.00 | 3.00 | 3.00 |
| 9 | 0.00 | 2.00 | 175.00 | 19.00 | 3.50 | 3.50 | 4.00 | 2.00 |
| 10 | 0.00 | 2.00 | 105.00 | 4.00 | 2.50 | 2.50 | 4.00 | 2.00 |
| 11 | 1.00 | M | 175.00 | 9.80 | 3.75 | 2.00 | 3.00 | 4.00 |
| 12 | 1.00 | 4.00 | 80.00 | 11.50 | 3.00 | 5.00 | 4.00 | 2.00 |
| 13 | 0.00 | M | 100.00 | 10.00 | 2.50 | 3.00 | 3.00 | 3.00 |
| 14 | 0.00 | M | 140.00 | 9.00 | 2.00 | 3.50 | 3.00 | 4.00 |
| 15 | 0.00 | 4.00 | 80.00 | 4.00 | 2.50 | 5.00 | 5.00 | 2.00 |
| 16 | 0.00 | 2.00 | 130.00 | 5.50 | M | 4.00 | 3.00 | 4.00 |
| 17 | 0.00 | 2.00 | 80.00 | 3.75 | 1.50 | 2.30 | 4.00 | 2.00 |
| 18 | 0.00 | 2.00 | 75.00 | 4.00 | 2.50 | 2.50 | 3.00 | 4.00 |
| 19 | M | M | M | M | M | M | M | M |
| 20 | 1.00 | 1.00 | 100.00 | 5.00 | M | 3.00 | 2.00 | 5.00 |
| 21 | 0.00 | 2.00 | 60.00 | 3.70 | 2.50 | 3.50 | 3.00 | 4.00 |
| 22 | M | 2.00 | 200.00 | 9.20 | 4.00 | 3.00 | 4.00 | 4.00 |
| 23 | 0.00 | 2.00 | 116.00 | 5.40 | 1.00 | 2.50 | 3.00 | 4.00 |
| 24 | 0.00 | M | 148.00 | 13.00 | 3.00 | 3.50 | 4.00 | 2.00 |
| 25 | 0.00 | M | 80.00 | 3.75 | 2.00 | 3.00 | 3.00 | 3.00 |
| 26 | 2.00 | M | 80.00 | 5.00 | 3.00 | 3.50 | 3.00 | 3.00 |
| 27 | 0.00 | M | 80.00 | 3.30 | 2.50 | 3.00 | 4.00 | M |
| 28 | 0.00 | 2.00 | 164.00 | 7.00 | 3.00 | 3.00 | 4.00 | 2.00 |
| 29 | 2.00 | 4.00 | 120.00 | 4.50 | 2.00 | 2.00 | 5.00 | 2.00 |
| 30 | 0.00 | M | 100.00 | 2.75 | 1.00 | 2.50 | 4.00 | 2.00 |
| 31 | 2.00 | 4.00 | 80.00 | 5.00 | 4.00 | 3.50 | 4.00 | 4.00 |
| 32 | 1.00 | M | 185.00 | 13.50 | 4.00 | 2.50 | 4.00 | 2.00 |
| 33 | 1.00 | 2.00 | 200.00 | 12.00 | 2.50 | 2.00 | 4.00 | 4.00 |
| 34 | 4.00 | 4.00 | 65.00 | 2.00 | 2.00 | 3.00 | 3.00 | 4.00 |
| 35 | 1.00 | 4.00 | 120.00 | 4.75 | 2.00 | 1.50 | 2.00 | 3.00 |
| 36 | 1.00 | M | 80.00 | 4.00 | 2.50 | 2.50 | 3.00 | 4.00 |
| 37 | 0.00 | M | 80.00 | 3.70 | 1.50 | M | M | M |
| 38 | 0.00 | 2.00 | 170.00 | 3.00 | 1.00 | 2.00 | 5.00 | 3.00 |
| 39 | 0.00 | M | 82.00 | 11.00 | 2.00 | M | 3.00 | 4.00 |
| 40 | 1.00 | M | 102.00 | 5.75 | M | 2.50 | 4.00 | 3.00 |
| 41 | 0.00 | M | 100.00 | 5.75 | 2.50 | 3.75 | 3.00 | 4.00 |
| 42 | 0.00 | 1.00 | 104.00 | 8.30 | 4.00 | 2.50 | 3.00 | 2.00 |
| 43 | 0.00 | M | 120.00 | 7.50 | 1.00 | 3.00 | 3.00 | 2.00 |

| CASE | SAPERA | LIP | SPI | PKPI | VTPI | LIPI | NOUS | NORR |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.00 | 3.00 | 59.00 | 5.00 | 3.00 | 3.00 | 69.00 | 19.00 |
| 2 | 2.00 | 2.00 | 51.10 | 5.00 | 4.00 | 1.00 | 69.00 | M |
| 3 | 2.00 | 2.00 | 130.00 | M | M | M | M | M |
| 4 | 4.00 | 3.00 | 123.00 | 3.00 | 4.00 | 2.00 | M | M |
| 5 | 3.00 | 3.00 | 94.10 | 3.00 | 4.00 | 3.00 | 99.00 | 40.00 |
| 6 | 4.00 | 3.00 | 93.30 | 2.00 | 4.00 | 3.00 | M | M |
| 7 | 2.00 | 4.00 | 124.80 | 1.00 | 3.00 | 2.00 | M | M |
| 8 | 4.00 | 4.00 | 111.90 | 3.00 | 4.00 | 3.00 | M | M |
| 9 | 1.00 | 4.00 | 116.60 | 2.00 | 3.00 | 2.00 | M | M |
| 10 | 2.00 | 3.00 | 115.80 | 4.00 | 4.00 | 2.00 | 132.00 | 75.00 |
| 11 | 4.00 | 4.00 | 59.90 | 4.00 | 3.00 | 2.00 | M | M |
| 12 | 2.00 | 4.00 | M | M | M | M | M | M |
| 13 | 3.00 | 2.00 | 103.00 | 4.00 | 4.00 | 2.00 | M | M |
| 14 | 4.00 | 3.00 | 96.00 | 5.00 | 4.00 | 4.00 | 200.00 | 66.00 |
| 15 | 2.00 | 1.00 | 156.00 | 4.00 | 3.00 | 3.00 | M | M |
| 16 | 4.00 | 3.00 | 226.00 | 3.00 | 3.00 | 3.00 | 60.00 | 54.00 |
| 17 | 3.00 | 3.00 | 163.00 | 4.00 | 3.00 | 2.00 | M | M |
| 18 | 2.00 | M | 99.00 | 2.00 | 4.00 | 3.00 | M | M |
| 19 | M | M | 122.00 | 2.00 | 3.00 | 3.00 | M | M |
| 20 | 5.00 | 2.00 | 107.10 | 3.00 | 4.00 | 3.00 | M | M |
| 21 | 4.00 | 2.00 | 78.40 | 4.00 | 4.00 | 3.00 | 177.00 | 94.00 |
| 22 | 4.00 | 5.00 | 195.00 | 3.00 | 3.00 | 5.00 | 20.00 | 12.00 |
| 23 | 2.00 | 4.00 | M | M | M | M | M | M |
| 24 | 2.00 | 4.00 | 139.00 | 3.00 | M | M | M | M |
| 25 | 4.00 | 3.00 | 123.30 | 4.00 | 3.00 | 4.00 | M | M |
| 26 | 3.00 | 2.00 | 90.80 | 2.00 | 2.00 | 4.00 | M | M |
| 27 | M | M | 106.00 | 3.00 | 3.00 | 1.00 | M | M |
| 28 | 2.00 | 3.00 | 189.00 | 3.00 | 4.00 | 3.00 | M | M |
| 29 | 2.00 | 4.00 | 114.40 | 5.00 | 3.00 | 4.00 | 65.00 | 18.00 |
| 30 | 1.00 | 3.00 | 248.00 | 4.00 | M | M | 65.00 | 48.00 |
| 31 | 4.00 | 4.00 | M | M | M | M | M | M |
| 32 | 2.00 | 4.00 | 137.10 | 2.00 | 3.00 | 4.00 | 102.00 | 47.00 |
| 33 | 4.00 | 5.00 | M | M | M | M | M | M |
| 34 | 3.00 | 4.00 | 112.00 | 3.00 | 2.00 | 3.00 | M | M |
| 35 | 4.00 | 2.00 | 142.10 | 4.00 | 3.00 | 2.00 | M | M |
| 36 | 4.00 | 3.50 | 79.10 | 1.00 | 3.00 | 3.50 | 283.00 | 90.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 4.00 | 2.00 | M | 5.00 | 4.00 | 1.00 | 75.00 | 50.00 |
| 39 | 4.00 | 2.00 | M | M | M | M | M | M |
| 40 | 3.00 | 3.00 | 92.80 | 2.00 | 3.00 | 4.00 | 247.00 | 127.00 |
| 41 | 4.00 | 3.00 | 79.70 | 4.00 | 4.00 | 3.00 | 40.00 | 21.00 |
| 42 | 3.00 | 3.00 | 198.90 | 4.00 | 3.00 | 3.00 | 255.00 | 70.00 |
| 43 | 3.00 | 3.00 | 104.10 | 1.00 | 2.00 | 1.00 | 52.00 | 22.00 |

| CASE | USATA | USATB | USATC | USATD | USATE | USATNA | IMPA | IMPB |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 6.00 | 2.00 | 8.00 | 2.00 | 1.00 | 0.00 | 3.00 |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 10.00 | 19.00 | 3.00 | 8.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | M | M | M | M | M | M | M | M |
| 9 | M | M | M | M | M | M | M | M |
| 10 | 12.00 | 33.00 | 5.00 | 22.00 | 3.00 | 0.00 | 1.00 | 6.00 |
| 11 | M | M | M | M | M | M | M | M |
| 12 | M | M | M | M | M | M | M | M |
| 13 | M | M | M | M | M | M | M | M |
| 14 | 3.00 | 23.00 | 4.00 | 33.00 | 5.00 | 0.00 | 1.00 | 4.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | 2.00 | 24.00 | 0.00 | 28.00 | 0.00 | 0.00 | 0.00 | 33.00 |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | M | M | M | M | M | M |
| 19 | M | M | M | M | M | M | M | M |
| 20 | M | M | M | M | M | M | M | M |
| 21 | 10.00 | 27.00 | 11.00 | 41.00 | 5.00 | 0.00 | 2.00 | 5.00 |
| 22 | 1.00 | 5.00 | 1.00 | 5.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | M |
| 26 | M | M | M | M | M | M | M | M |
| 27 | M | M | M | M | M | M | M | M |
| 28 | M | M | M | M | M | M | M | M |
| 29 | 3.00 | 12.00 | 1.00 | 2.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| 30 | 7.00 | 31.00 | 10.00 | 0.00 | 0.00 | 0.00 | 7.00 | 31.00 |
| 31 | M | M | M | M | M | M | M | M |
| 32 | 8.00 | 16.00 | 8.00 | 15.00 | 0.00 | 0.00 | 1.00 | 3.00 |
| 33 | M | M | M | M | M | M | M | M |
| 34 | M | M | M | M | M | M | M | M |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 3.00 | 20.00 | 24.00 | 36.00 | 6.00 | 194.00 | 3.00 | 7.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 0.00 | 5.00 | 3.00 | 30.00 | 10.00 | 2.00 | 3.00 | 3.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 18.00 | 29.00 | 29.00 | 28.00 | 7.00 | 16.00 | 1.00 | 11.00 |
| 41 | 2.00 | 6.00 | 4.00 | 9.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| 42 | 17.00 | 29.00 | 11.00 | 13.00 | 0.00 | 0.00 | 0.00 | 4.00 |
| 43 | 2.00 | 7.00 | 5.00 | 8.00 | 0.00 | 33.00 | 0.00 | 2.00 |

| CASE | IMPC | IMPD | IMPE | IMPNA | WAITA | WAITB | WAITC | WAITD |
|---|---|---|---|---|---|---|---|---|
| 1 | 6.00 | 9.00 | 0.00 | 1.00 | 4.00 | 10.00 | 3.00 | 1.00 |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 10.00 | 19.00 | 9.00 | 0.00 | 0.00 | 10.00 | 12.00 | 10.00 |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | M | M | M | M | M | M | M | M |
| 9 | M | M | M | M | M | M | M | M |
| 10 | 36.00 | 26.00 | 6.00 | 0.00 | 6.00 | 17.00 | 20.00 | 18.00 |
| 11 | M | M | M | M | M | M | M | M |
| 12 | M | M | M | M | M | M | M | M |
| 13 | M | M | M | M | M | M | M | M |
| 14 | 23.00 | 26.00 | 13.00 | 0.00 | 11.00 | 22.00 | 14.00 | 7.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | 19.00 | 2.00 | 0.00 | 0.00 | 0.00 | 13.00 | 22.00 | 19.00 |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | M | M | M | M | M | M |
| 19 | M | M | M | M | M | M | M | M |
| 20 | M | M | M | M | M | M | M | M |
| 21 | 36.00 | 50.00 | 1.00 | 0.00 | 10.00 | 29.00 | 34.00 | 19.00 |
| 22 | 4.00 | 6.00 | 1.00 | 0.00 | 1.00 | 3.00 | 2.00 | 4.00 |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | M |
| 26 | M | M | M | M | M | M | M | M |
| 27 | M | M | M | M | M | M | M | M |
| 28 | M | M | M | M | M | M | M | M |
| 29 | 2.00 | 8.00 | 7.00 | 0.00 | 0.00 | 0.00 | 9.00 | 6.00 |
| 30 | 10.00 | 0.00 | 0.00 | 0.00 | 7.00 | 31.00 | 10.00 | 0.00 |
| 31 | M | M | M | M | M | M | M | M |
| 32 | 22.00 | 18.00 | 3.00 | 0.00 | 2.00 | 8.00 | 14.00 | 14.00 |
| 33 | M | M | M | M | M | M | M | M |
| 34 | M | M | M | M | M | M | M | M |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 46.00 | 25.00 | 5.00 | 197.00 | 8.00 | 28.00 | 28.00 | 16.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 20.00 | 15.00 | 8.00 | 1.00 | 21.00 | 9.00 | 4.00 | 0.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 53.00 | 38.00 | 10.00 | 14.00 | 7.00 | 15.00 | 20.00 | 29.00 |
| 41 | 8.00 | 10.00 | 2.00 | 0.00 | 5.00 | 3.00 | 6.00 | 3.00 |
| 42 | 19.00 | 27.00 | 20.00 | 0.00 | 4.00 | 20.00 | 19.00 | 10.00 |
| 43 | 9.00 | 8.00 | 3.00 | 30.00 | 3.00 | 4.00 | 6.00 | 3.00 |

| CASE | WAITE | WAITF | WAITNA | PKUSIA | LIUSIA | SBUFF | SBUFFF | SCBF |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 1.00 | 2.00 | 3.00 | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | 104.00 | 1.00 | 1.00 |
| 4 | M | M | M | M | M | 160.00 | 1.00 | 0.00 |
| 5 | 3.00 | 5.00 | 0.00 | 2.00 | 4.00 | 240.00 | 1.00 | 0.00 |
| 6 | M | M | M | M | M | 400.00 | 0.00 | 1.00 |
| 7 | M | M | M | M | M | M | M | M |
| 8 | M | M | M | M | M | M | M | M |
| 9 | M | M | M | M | M | M | M | M |
| 10 | 9.00 | 5.00 | 0.00 | 2.00 | 3.00 | 200.00 | 1.00 | 0.00 |
| 11 | M | M | M | M | M | 140.00 | 0.00 | 0.00 |
| 12 | M | M | M | M | M | M | M | M |
| 13 | M | M | M | M | M | 510.00 | 1.00 | 0.00 |
| 14 | 9.00 | 4.00 | 0.00 | 4.00 | 4.00 | 198.00 | 0.00 | 0.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | 0.00 | 0.00 | 0.00 | 4.00 | 4.00 | M | M | M |
| 17 | M | M | M | M | M | 400.00 | 1.00 | 0.00 |
| 18 | M | M | M | M | M | M | M | M |
| 19 | M | M | M | M | M | M | M | M |
| 20 | M | M | M | M | M | M | M | M |
| 21 | 2.00 | 0.00 | 0.00 | 2.00 | 4.00 | 320.00 | 0.00 | 0.00 |
| 22 | 1.00 | 0.00 | 0.00 | 4.00 | 4.00 | 400.00 | 1.00 | 0.00 |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | 64.00 | 1.00 | 1.00 |
| 26 | M | M | M | M | M | 200.00 | 1.00 | 0.00 |
| 27 | M | M | M | M | M | 300.00 | 1.00 | 0.00 |
| 28 | M | M | M | M | M | 120.00 | 1.00 | 0.00 |
| 29 | 2.00 | 1.00 | 0.00 | 5.00 | 2.00 | 128.00 | 1.00 | 1.00 |
| 30 | 0.00 | 0.00 | 0.00 | 4.00 | 3.00 | M | M | M |
| 31 | M | M | M | 2.00 | 3.00 | M | M | M |
| 32 | 5.00 | 4.00 | 0.00 | 2.00 | 4.00 | 250.00 | 0.00 | 0.00 |
| 33 | M | M | M | M | M | M | M | M |
| 34 | M | M | M | M | M | 510.00 | 0.00 | 1.00 |
| 35 | M | M | M | M | M | 400.00 | 0.00 | 1.00 |
| 36 | 5.00 | 1.00 | 197.00 | 2.00 | 3.00 | 140.00 | 0.00 | 0.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 0.00 | 0.00 | 15.00 | 2.00 | 3.00 | M | M | M |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 25.00 | 14.00 | 17.00 | 2.00 | 3.00 | M | M | M |
| 41 | 4.00 | 0.00 | 0.00 | 3.00 | 3.00 | 254.00 | 0.00 | 1.00 |
| 42 | 6.00 | 10.00 | 1.00 | 4.00 | 3.00 | 254.00 | 0.00 | 1.00 |
| 43 | 3.00 | 0.00 | 30.00 | M | M | 40.00 | 1.00 | 0.00 |

| CASE | SHR | SMR | PKSA | LISA | VCBUFF | VCHR | VCMR | PKVCA |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | 0.85 | 9.80 | M | M | 80.00 | 0.60 | 5.47 | 4.00 |
| 4 | 0.87 | 6.24 | 4.00 | 1.00 | M | M | M | M |
| 5 | 0.67 | 16.30 | 3.00 | 2.00 | 128.00 | 0.69 | 6.66 | 4.00 |
| 6 | 0.75 | 5.80 | 2.00 | 2.00 | 200.00 | 0.84 | 1.10 | 4.00 |
| 7 | M | M | M | M | 128.00 | 0.77 | 3.22 | 4.00 |
| 8 | M | M | M | M | 255.00 | 0.95 | 0.52 | 2.00 |
| 9 | M | M | M | M | M | M | M | M |
| 10 | 0.72 | 5.40 | 3.00 | 2.00 | 100.00 | 0.80 | 2.87 | 3.00 |
| 11 | 0.98 | 11.19 | 4.00 | 2.00 | M | M | M | M |
| 12 | M | M | M | M | M | M | M | M |
| 13 | 0.84 | 6.30 | 3.00 | 2.00 | 255.00 | 0.92 | 0.85 | 3.00 |
| 14 | 0.87 | 6.50 | 2.00 | 4.00 | M | M | M | M |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | M | M | M | M | M | M | M |
| 17 | 0.90 | 5.50 | 4.00 | 3.00 | 32.00 | 0.55 | 5.40 | 5.00 |
| 18 | M | M | M | M | M | M | M | M |
| 19 | M | M | M | M | M | M | M | M |
| 20 | M | M | M | M | M | M | M | M |
| 21 | 0.80 | 6.20 | 2.00 | 3.00 | 160.00 | 0.94 | 0.61 | 3.00 |
| 22 | M | M | M | M | M | M | M | M |
| 23 | M | M | M | M | M | 0.71 | 3.72 | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | 0.96 | 6.88 | 3.00 | 4.00 | M | M | M | M |
| 26 | 0.78 | 3.93 | M | M | 120.00 | M | M | M |
| 27 | 0.86 | 3.00 | 3.00 | 3.00 | M | M | M | M |
| 28 | 0.77 | 57.00 | 3.00 | 3.00 | 40.00 | M | M | 2.00 |
| 29 | 0.69 | 16.50 | 5.00 | 3.00 | 96.00 | 0.74 | 1.14 | 5.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | M | M | M | M | M | M | M | M |
| 32 | 0.76 | 7.80 | 2.00 | 4.00 | 120.00 | 0.71 | 4.63 | 2.00 |
| 33 | M | M | M | M | M | M | M | M |
| 34 | 0.67 | 11.34 | 2.00 | 4.00 | M | M | M | M |
| 35 | M | M | 4.00 | 2.00 | M | M | M | M |
| 36 | 0.79 | 3.72 | 2.00 | 3.50 | 60.00 | 0.77 | 1.10 | 2.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | M | M | M | M | M | M | M | M |
| 39 | M | M | M | M | M | M | M | M |
| 40 | M | M | M | M | M | M | M | M |
| 41 | 0.81 | 6.40 | 4.00 | 3.00 | 50.00 | 0.79 | 1.30 | 2.00 |
| 42 | 0.62 | 7.67 | 5.00 | 1.00 | 255.00 | M | M | 5.00 |
| 43 | 0.69 | 17.30 | M | M | 255.00 | 0.93 | 0.78 | 2.00 |

| CASE | LIVCA | UPS | UVERR | UVERRP | UVERRV | UVERRC | UVERRN | UVERRM |
|---|---|---|---|---|---|---|---|---|
| 1 | M | 0.00 | 3.00 | 12.00 | 3.00 | 2.00 | 0.00 | 0.00 |
| 2 | M | 1.00 | 1.00 | 36.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| 3 | 2.00 | 0.00 | 1.00 | 24.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 1.00 | 0.00 | 2.00 | 9.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 2.00 | 0.00 | 1.00 | 43.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| 7 | 1.00 | M | M | M | M | M | M | M |
| 8 | 2.00 | 1.00 | 0.00 | 36.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9 | M | 0.00 | 3.00 | 36.00 | 2.00 | 1.00 | 1.00 | 0.00 |
| 10 | 2.00 | 0.00 | 2.00 | 12.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | M | 1.00 | 0.00 | 24.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 12 | M | 0.00 | 1.00 | 12.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13 | 2.00 | M | 8.00 | 6.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| 14 | M | 0.00 | 27.00 | 24.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | 0.00 | 3.00 | 6.00 | 2.00 | 2.00 | 1.00 | 0.00 |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | M | M | M | M | M | M |
| 19 | M | 1.00 | 6.00 | 12.00 | 6.00 | 6.00 | 0.00 | 0.00 |
| 20 | M | 0.00 | 2.00 | 42.00 | 2.00 | 2.00 | 0.00 | 0.00 |
| 21 | 2.00 | 0.00 | 40.00 | 36.00 | 1.00 | 1.00 | 0.00 | 0.00 |
| 22 | M | 0.00 | 6.00 | 36.00 | 2.00 | 0.00 | 0.00 | 0.00 |
| 23 | M | 0.00 | 3.00 | 27.00 | 3.00 | 0.00 | 0.00 | 0.00 |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | 0.00 | M | M | M | M | M | M |
| 26 | M | M | M | M | M | M | M | M |
| 27 | M | M | M | M | M | M | M | M |
| 28 | 3.00 | 0.00 | 4.00 | 4.00 | 4.00 | 0.00 | 4.00 | 0.00 |
| 29 | 3.00 | 1.00 | 2.00 | 36.00 | 2.00 | 0.00 | 0.00 | 0.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | M | 0.00 | 7.00 | 18.00 | 1.00 | 0.00 | 1.00 | 0.00 |
| 32 | 3.00 | 1.00 | 1.00 | 42.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 33 | M | 0.00 | 1.00 | 36.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 34 | M | 0.00 | 5.00 | 12.00 | 5.00 | 0.00 | 0.00 | 0.00 |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 3.00 | 0.00 | 3.00 | 36.00 | 3.00 | 0.00 | 3.00 | 0.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | M | M | 1.00 | 9.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | M | 1.00 | 1.00 | 12.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 41 | 3.00 | 0.00 | 1.00 | 41.00 | 0.0C | 0.00 | 0.00 | 0.00 |
| 42 | 1.00 | M | M | M | M | M | M | M |
| 43 | 3.00 | 0.00 | 4.00 | 36.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| CASE | LIWFC | PKDDA | LIDDA | FLU | NFLFO | PKF | LIFA | PKPPA |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.00 | 1.00 | 3.00 | M | M | M | M | M |
| 2 | 1.00 | 2.00 | 2.00 | M | M | M | M | 5.00 |
| 3 | 2.00 | 4.00 | 2.00 | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 1.00 | 1.00 | 4.00 | 0.00 | 0 | M | M | 2.00 |
| 6 | 1.00 | 2.00 | 5.00 | 1.00 | M | M | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | 1.00 | 1.00 | 5.00 | M | M | M | M | 2.00 |
| 9 | 1.00 | 2.00 | 4.00 | M | M | M | M | 2.00 |
| 10 | 1.00 | 1.00 | 5.00 | 1.00 | 4.00 | 2.00 | 3.00 | 2.00 |
| 11 | 1.00 | 1.00 | 5.00 | 0.00 | 0 | M | M | 3.00 |
| 12 | 1.00 | 4.00 | 5.00 | 1.00 | 6.00 | M | M | M |
| 13 | M | 3.00 | 2.00 | 1.00 | 5.00 | 3.00 | 2.00 | 3.00 |
| 14 | 0.00 | 3.00 | 3.00 | M | M | M | M | 4.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | 0.00 | 2.00 | 4.00 | M | M | M | M | M |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | M | M | M | M | M | 2.00 |
| 19 | 0.00 | 2.00 | 3.00 | M | M | M | M | M |
| 20 | 1.00 | 1.00 | 4.00 | M | M | M | M | 1.00 |
| 21 | 2.00 | 3.00 | 3.00 | 1.00 | 7.00 | 3.00 | 3.00 | 4.00 |
| 22 | 0.00 | 2.00 | 4.00 | M | M | M | M | M |
| 23 | 0.00 | 2.00 | 3.00 | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | 1.00 | 3.00 | 3.00 | M | M | M | M | M |
| 26 | M | M | M | M | M | M | M | 2.00 |
| 27 | M | M | M | 1.00 | 6.00 | M | M | M |
| 28 | 1.00 | 1.00 | 5.00 | M | M | M | M | 3.00 |
| 29 | 0.00 | 5.00 | 3.00 | 1.00 | 5.00 | 4.00 | 3.00 | 5.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | 0.00 | 2.00 | 3.00 | M | M | M | M | M |
| 32 | 1.00 | 1.00 | 5.00 | 0.00 | 0.00 | 2.00 | 3.00 | 2.00 |
| 33 | 1.00 | 1.00 | 5.00 | M | M | M | M | 2.00 |
| 34 | 1.00 | 1.00 | 5.00 | M | M | M | M | M |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 1.00 | 1.00 | 4.00 | 1.00 | 10.00 | 1.00 | 4.00 | 2.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 1.00 | 2.00 | 1.00 | 0.00 | 0.00 | M | M | 4.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 1.00 | 2.00 | 4.00 | M | M | M | M | 2.00 |
| 41 | M | 2.00 | 3.00 | 1.00 | 16.00 | 2.00 | 3.00 | 4.00 |
| 42 | M | M | M | M | M | M | M | M |
| 43 | 0.00 | 2.00 | 4.00 | 0.00 | 0 | M | M | 2.00 |

| CASE | LIPPA | PKIOBN | LIIOBNA | PKPFC | LIFPFC |
|---|---|---|---|---|---|
| 1 | M | M | M | M | M |
| 2 | 1.00 | 5.00 | 2.00 | M | M |
| 3 | M | M | M | M | M |
| 4 | M | M | M | 4.00 | 1.00 |
| 5 | 4.00 | M | M | 2.00 | 2.00 |
| 6 | M | M | M | M | M |
| 7 | M | M | M | 4.00 | 1.00 |
| 8 | 4.00 | M | M | M | M |
| 9 | 4.00 | M | M | M | M |
| 10 | 4.00 | M | M | 2.00 | 2.00 |
| 11 | 3.00 | M | M | 3.00 | 3.00 |
| 12 | M | M | M | 4.00 | 3.00 |
| 13 | 2.00 | 3.00 | 2.00 | M | M |
| 14 | 2.00 | 4.00 | 3.00 | M | M |
| 15 | M | M | M | M | M |
| 16 | M | M | M | M | M |
| 17 | M | M | M | 4.00 | 3.00 |
| 18 | 3.00 | M | M | M | M |
| 19 | M | 2.00 | 2.00 | 2.00 | 3.00 |
| 20 | 4.00 | M | M | M | M |
| 21 | 3.00 | M | M | 4.00 | 3.00 |
| 22 | M | M | M | M | M |
| 23 | M | M | M | M | M |
| 24 | M | M | M | M | M |
| 25 | M | M | M | M | M |
| 26 | 1.00 | M | M | M | M |
| 27 | M | 5.00 | 1.00 | M | M |
| 28 | 3.00 | 2.00 | 3.00 | 2.00 | 3.00 |
| 29 | 3.00 | 5.00 | 1.00 | 4.00 | 2.00 |
| 30 | M | M | M | M | M |
| 31 | M | 4.00 | 2.00 | 4.00 | 1.00 |
| 32 | 4.00 | M | M | 2.00 | 4.00 |
| 33 | 4.00 | M | M | M | M |
| 34 | M | 2.00 | 4.00 | M | M |
| 35 | M | M | M | M | M |
| 36 | 3.00 | M | M | 2.00 | 2.00 |
| 37 | M | M | M | M | M |
| 38 | 3.00 | M | M | 3.00 | 3.00 |
| 39 | M | M | M | M | M |
| 40 | 4.00 | M | M | M | M |
| 41 | 2.00 | M | M | M | M |
| 42 | M | M | M | M | M |
| 43 | 2.00 | M | M | 2.00 | 3.00 |

Data Base 2

| CASE | SP1C | SP1IP | SP1V | SP2C | SP2IP | SP2V | SP3C | SP3IP |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | 5400.00 | 3.00 | 5.00 | M | M | M | M | M |
| 4 | M | M | M | M | 3.00 | 4.00 | M | M |
| 5 | M | M | M | M | M | M | M | 3.00 |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | M | M | M | M | M | M | M | 3.00 |
| 9 | M | M | M | M | M | M | M | M |
| 10 | M | M | M | M | M | M | M | M |
| 11 | M | M | M | 1695.00 | 4.00 | 5.00 | M | M |
| 12 | M | M | M | 1200.00 | 4.00 | 5.00 | M | M |
| 13 | M | M | M | M | M | M | M | M |
| 14 | M | M | M | M | M | M | M | M |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | M | M | M | M | M | M | M |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | M | M | M | M | M | M |
| 19 | M | M | M | M | M | M | M | M |
| 20 | M | M | M | M | M | M | M | M |
| 21 | M | M | M | M | M | M | M | M |
| 22 | 1000.00 | 4.00 | 5.00 | M | M | M | M | M |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | M |
| 26 | M | M | M | 900.00 | 4.00 | 4.00 | M | M |
| 27 | M | M | M | M | M | M | M | M |
| 28 | M | M | M | M | M | M | M | M |
| 29 | 5000.00 | 3.00 | 5.00 | M | M | M | M | 3.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | M | M | M | M | M | M | 0.00 | 2.00 |
| 32 | 6150.00 | 3.00 | 5.00 | M | M | M | M | M |
| 33 | M | M | M | M | M | M | M | M |
| 34 | M | M | M | M | M | M | 0.00 | 3.00 |
| 35 | 5390.00 | 4.00 | 4.00 | M | M | M | M | M |
| 36 | M | M | M | M | M | M | M | M |
| 37 | M | M | M | M | M | M | M | M |
| 38 | M | M | M | M | M | M | M | M |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 500.00 | 3.00 | 4.00 | M | M | M | M | M |
| 41 | M | M | M | M | M | M | M | M |
| 42 | M | M | M | M | M | M | M | M |
| 43 | M | M | M | M | M | M | M | M |

| CASE | SP3V | SP4C | SP4IP | SP4V | SP5C | SP5IP | SP5V | D1FEXNT |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | 43.00 |
| 2 | M | M | M | M | M | M | M | 70.00 |
| 3 | M | M | M | M | M | M | M | 31.00 |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 4.00 | M | M | M | M | M | M | 99.00 |
| 6 | M | M | M | M | M | M | M | 14.00 |
| 7 | M | M | M | M | M | M | M | M |
| 8 | 4.00 | M | 3.00 | 1.00 | M | M | M | 17.00 |
| 9 | M | M | M | M | M | M | M | 14.00 |
| 10 | M | M | M | M | M | M | M | 26.00 |
| 11 | M | M | M | M | M | M | M | 27.00 |
| 12 | M | M | M | M | M | M | M | M |
| 13 | M | M | M | M | M | M | M | 95.00 |
| 14 | M | M | M | M | M | M | M | 48.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | M | M | M | M | M | M | 28.00 |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | M | M | M | M | M | M |
| 19 | M | M | M | M | M | M | M | 24.00 |
| 20 | M | M | 3.00 | 4.00 | M | M | M | 18.00 |
| 21 | M | M | M | M | M | M | M | 52.00 |
| 22 | M | M | M | M | M | M | M | 12.00 |
| 23 | M | M | M | M | M | M | M | 66.00 |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | 26.00 |
| 26 | M | M | M | M | 1200.00 | 4.00 | 5.00 | M |
| 27 | M | M | M | M | 1200.00 | 4.00 | 4.00 | M |
| 28 | M | M | M | M | M | M | M | M |
| 29 | 3.00 | M | M | M | M | M | M | 23.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | 4.00 | M | 1.00 | 3.00 | M | M | M | 3.00 |
| 32 | M | M | M | M | M | M | M | 22.00 |
| 33 | M | M | 1.00 | M | M | M | M | 36.00 |
| 34 | 4.00 | M | M | M | M | M | M | 103.00 |
| 35 | M | M | M | M | M | M | M | M |
| 36 | M | M | M | M | 1200.00 | 4.00 | 4.00 | 3.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | M | M | M | M | M | M | M | 52.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | M | M | M | M | M | M | M | 31.00 |
| 41 | M | M | M | M | M | M | M | 15.00 |
| 42 | M | M | M | M | M | M | M | M |
| 43 | M | M | M | M | M | M | M | 42.00 |

| CASE | D2FEXNT | D3FEXNT | D4FEXNT | D5FEXNT | D6FEXNT | D7FEXNT | D8FEXNT | D1FTS |
|---|---|---|---|---|---|---|---|---|
| 1 | 32.00 | 10.00 | 27.00 | 16.00 | 16.00 | M | M | 2.00 |
| 2 | 13.00 | 50.00 | 7.00 | 39.00 | 171.00 | 8.00 | M | 1.00 |
| 3 | 27.00 | 23.00 | 18.00 | 25.00 | 40.00 | M | M | 3.00 |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 24.00 | 11.00 | 42.00 | 58.00 | 81.00 | 33.00 | M | 2.00 |
| 6 | 90.00 | 157.00 | 49.00 | 34.00 | 191.00 | 44.00 | M | 1.00 |
| 7 | M | M | M | M | M | M | M | M |
| 8 | 1.00 | 4.00 | 5.00 | 13.00 | 49.00 | M | M | 1.00 |
| 9 | 1.00 | 40.00 | 11.00 | 70.00 | 55.00 | M | M | 1.00 |
| 10 | 24.00 | 3.00 | 17.00 | 56.00 | 20.00 | 63.00 | 35.00 | 2.00 |
| 11 | 108.00 | 14.00 | 21.00 | 13.00 | M | M | M | 1.00 |
| 12 | M | M | M | M | M | M | M | M |
| 13 | 12.00 | 102.00 | 19.00 | 34.00 | 15.00 | 111.00 | 195.00 | 2.00 |
| 14 | 24.00 | 34.00 | 93.00 | 72.00 | 46.00 | M | M | 1.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | 15.00 | 3.00 | 15.00 | 27.00 | 21.00 | M | M | 2.00 |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | M | M | M | M | M | M |
| 19 | 18.00 | 55.00 | 51.00 | 32.00 | 62.00 | M | M | 2.00 |
| 20 | 55.00 | 22.00 | 26.00 | 28.00 | 37.00 | M | M | 2.00 |
| 21 | 42.00 | 50.00 | 41.00 | 9.00 | 14.00 | M | M | 1.00 |
| 22 | 84.00 | 1.00 | 3.00 | 54.00 | 48.00 | 30.00 | 147.00 | 1.00 |
| 23 | 53.00 | 90.00 | 52.00 | 391.00 | 157.00 | M | M | 2.00 |
| 24 | M | M | M | M | M | M | M | M |
| 25 | 37.00 | 41.00 | 44.00 | 79.00 | 44.00 | M | M | 2.00 |
| 26 | M | M | M | M | M | M | M | M |
| 27 | M | M | M | M | M | M | M | M |
| 28 | M | M | M | M | M | M | M | M |
| 29 | 130.00 | 67.00 | 158.00 | 10.00 | 72.00 | 77.00 | 117.00 | 1.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | 1.00 | 30.00 | 13.00 | 85.00 | 5.00 | M | M | 1.00 |
| 32 | 18.00 | 31.00 | 22.00 | 83.00 | 62.00 | M | M | 2.00 |
| 33 | 21.00 | 10.00 | 1.00 | 29.00 | 26.00 | 34.00 | 4.00 | 1.00 |
| 34 | 51.00 | 20.00 | 208.00 | 4.00 | 8.00 | 9.00 | 63.00 | 1.00 |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 43.00 | 41.00 | 29.00 | 40.00 | 7.00 | 60.00 | M | 1.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 38.00 | 98.00 | 32.00 | 90.00 | 81.00 | M | M | 1.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 31.00 | 66.00 | 41.00 | 47.00 | 22.00 | M | M | 1.00 |
| 41 | 107.00 | 14.00 | 19.00 | 160.00 | 73.00 | M | M | 1.00 |
| 42 | M | M | M | M | M | M | M | M |
| 43 | 23.00 | 20.00 | 31.00 | 15.00 | 12.00 | M | M | 2.00 |

| CASE | D2FTS | D3FTS | D4FTS | D5FTS | D6FTS | D7FTS | D8FTS | D1PF |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | M | M | 70.00 |
| 2 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | M | 75.00 |
| 3 | 3.00 | 3.00 | 3.00 | 3.00 | 2.00 | M | M | 74.00 |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | M | 82.00 |
| 6 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | M | 25.00 |
| 7 | M | M | M | M | M | M | M | M |
| 8 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | M | M | 47.00 |
| 9 | 2.00 | 2.00 | 1.00 | 1.00 | 1.00 | M | M | 58.00 |
| 10 | 2.00 | 1.00 | 2.00 | 1.00 | 1.00 | 2.00 | 1.00 | 61.00 |
| 11 | 1.00 | 1.00 | 1.00 | 1.00 | M | M | M | 65.00 |
| 12 | M | M | M | M | M | M | M | 75.00 |
| 13 | 2.00 | 1.00 | 1.00 | 1.00 | 2.00 | 2.00 | 2.00 | 86.00 |
| 14 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | M | M | 69.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | M | M | 85.00 |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | M | M | M | M | M | M |
| 19 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | M | M | 84.00 |
| 20 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | M | M | 82.00 |
| 21 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 57.00 |
| 22 | 2.00 | 1.00 | 3.00 | 3.00 | 2.00 | 1.00 | 2.00 | 17.00 |
| 23 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | M | M | 92.00 |
| 24 | M | M | M | M | M | M | M | M |
| 25 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | M | M | 67.00 |
| 26 | M | M | M | M | M | M | M | M |
| 27 | M | M | M | M | M | M | M | M |
| 28 | M | M | M | M | M | M | M | M |
| 29 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 85.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | M | M | 80.00 |
| 32 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | M | M | 66.00 |
| 33 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 82.00 |
| 34 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 89.00 |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | M | 53.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 1.00 | 1.00 | 2.00 | 1.00 | 1.00 | M | M | 88.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | M | M | 76.00 |
| 41 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | M | M | 79.00 |
| 42 | M | M | M | M | M | M | M | M |
| 43 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | M | M | 66.00 |

| CASE | D2PF | D3PF | D4PF | D5PF | D6PF | D7PF | D8PF | MDA |
|---|---|---|---|---|---|---|---|---|
| 1 | 33.00 | 79.00 | 51.00 | 52.00 | 52.00 | M | M | 1024.00 |
| 2 | 42.00 | 53.00 | 89.00 | 84.00 | 64.00 | 21.00 | M | 1024.00 |
| 3 | 75.00 | 84.00 | 68.00 | 55.00 | 63.00 | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 39.00 | 69.00 | 57.00 | 64.00 | 52.00 | 77.00 | M | 2048.00 |
| 6 | 50.00 | 51.00 | 77.00 | 67.00 | 36.00 | 59.00 | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | 65.00 | 58.00 | 76.00 | 76.00 | 75.00 | M | M | 1024.00 |
| 9 | 80.00 | 70.00 | 70.00 | 91.00 | 85.00 | M | M | 1536.00 |
| 10 | 52.00 | 22.00 | 64.00 | 65.00 | 59.00 | 64.00 | 58.00 | 1536.00 |
| 11 | 65.00 | 61.00 | 35.00 | 47.00 | M | M | M | 1536.00 |
| 12 | 93.00 | 72.00 | M | 59.00 | 71.00 | M | M | M |
| 13 | 62.00 | 81.00 | 63.00 | 17.00 | 81.00 | 80.00 | 41.00 | 2048.00 |
| 14 | 90.00 | 61.00 | 91.00 | 74.00 | 42.00 | M | M | 1024.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | 59.00 | 71.00 | 71.00 | 83.00 | 82.00 | M | M | M |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | M | M | M | M | M | 1536.00 |
| 19 | 85.00 | 77.00 | 84.00 | 63.00 | 64.00 | M | M | M |
| 20 | 27.00 | 70.00 | 57.00 | 83.00 | 37.00 | M | M | 1536.00 |
| 21 | 58.00 | 60.00 | 41.00 | 55.00 | 73.00 | 48.00 | 61.00 | 1536.00 |
| 22 | 73.00 | 57.00 | 85.00 | 51.00 | 56.00 | 85.00 | 60.00 | M |
| 23 | 56.00 | 72.00 | 70.00 | 83.00 | 70.00 | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | 61.00 | 62.00 | 68.00 | 78.00 | 88.00 | M | M | M |
| 26 | M | M | M | M | M | M | M | 2048.00 |
| 27 | M | M | M | M | M | M | M | M |
| 28 | M | M | M | M | M | M | M | 1536.00 |
| 29 | 56.00 | 54.00 | 73.00 | 72.00 | 67.00 | 77.00 | 58.00 | 1536.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | 63.00 | 80.00 | 69.00 | 68.00 | 37.00 | M | M | M |
| 32 | 49.00 | 74.00 | 64.00 | 51.00 | M | M | M | 1536.00 |
| 33 | 87.00 | 50.00 | 65.00 | 86.00 | 55.00 | 68.00 | 94.00 | 1536.00 |
| 34 | 61.00 | 55.00 | 48.00 | 62.00 | 92.00 | 77.00 | 58.00 | M |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 30.00 | 35.00 | 61.00 | 51.00 | 17.70 | 18.00 | M | 1024.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 29.00 | 77.00 | 86.00 | 30.00 | 50.00 | M | M | M |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 68.00 | 75.00 | 80.00 | 72.00 | 86.00 | M | M | 1024.00 |
| 41 | 63.00 | 72.00 | 67.00 | 71.00 | 67.00 | M | M | 1024.00 |
| 42 | M | M | M | M | M | M | M | M |
| 43 | 52.00 | 77.00 | 71.00 | 88.00 | 50.00 | M | M | 2000.00 |

| CASE | CR | PP | PP1S | PP1PU | PP1MC | PP2S | PP2PU | PP2MC |
|---|---|---|---|---|---|---|---|---|
| 1 | 250.00 | 5.00 | 19.50 | 3.90 | 81.00 | 19.50 | 4.40 | 74.00 |
| 2 | 400.00 | 3.00 | 29.30 | 2.40 | 80.00 | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 300.00 | 6.00 | M | M | M | 20.00 | 7.20 | 193.00 |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | 400.00 | 4.00 | 15.00 | 6.40 | 146.00 | M | M | M |
| 9 | 400.00 | 3.00 | 24.40 | 17.10 | 198.00 | M | M | M |
| 10 | 400.00 | 6.00 | 19.50 | 9.50 | 112.00 | 19.50 | 10.50 | 127.00 |
| 11 | 250.00 | 5.00 | 19.50 | 12.70 | 175.00 | 19.50 | 12.20 | 160.00 |
| 12 | M | M | M | M | M | M | M | M |
| 13 | 150.00 | 3.00 | M | M | M | 31.30 | 6.70 | 101.00 |
| 14 | 400.00 | 5.00 | 16.00 | 4.30 | 76.00 | 16.00 | 4.40 | 51.00 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | M | M | M | M | M | M | M |
| 17 | M | M | M | M | M | M | M | M |
| 18 | 350.00 | 6.00 | 16.00 | 8.90 | 347.00 | 16.00 | 10.30 | 140.00 |
| 19 | M | M | M | M | M | M | M | M |
| 20 | 400.00 | 3.00 | M | M | M | M | M | M |
| 21 | 400.00 | 6.00 | 20.00 | 7.60 | 86.00 | M | M | M |
| 22 | M | M | M | M | M | M | M | M |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | M |
| 26 | 400.00 | 6.00 | 31.90 | 12.90 | 213.00 | 15.60 | 9.00 | 151.00 |
| 27 | M | M | M | M | M | M | M | M |
| 28 | 300.00 | 6.00 | 31.30 | 12.70 | 183.00 | 15.60 | 8.90 | 98.00 |
| 29 | 400.00 | 4.00 | M | M | M | 30.00 | 15.00 | 182.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | M | M | M | M | M | M | M | M |
| 32 | 250.00 | 6.00 | 18.00 | 10.20 | 82.00 | 20.00 | 9.60 | 54.00 |
| 33 | 400.00 | 5.00 | M | M | M | M | M | M |
| 34 | M | M | M | M | M | M | M | M |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 400.00 | 4.00 | 12.00 | 6.60 | 199.00 | M | M | M |
| 37 | M | M | M | M | M | M | M | M |
| 38 | M | M | M | M | M | 29.00 | 16.90 | 65.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 400.00 | 6.00 | 16.00 | 7.50 | 179.00 | 16.00 | 7.00 | 155.00 |
| 41 | 400.00 | 6.00 | 7.80 | 1.80 | 155.00 | 7.80 | 2.30 | 147.00 |
| 42 | M | M | M | M | M | M | M | M |
| 43 | 400.00 | 6.00 | 8.00 | 2.70 | 179.00 | 8.00 | 1.80 | 240.00 |

| CASE | PP3S | PP3PU | PP3MC | PP4S | PP4PU | PP4MC | PP5S | PP5PU |
|---|---|---|---|---|---|---|---|---|
| 1 | 19.50 | 3.80 | 79.00 | 31.30 | 9.60 | 220.00 | 19.50 | 3.70 |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 19.50 | 7.00 | 197.00 | 19.50 | 8.00 | 209.00 | 31.30 | 12.50 |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | 25.00 | 6.80 | 80.00 | M | M | M | 25.00 | 11.50 |
| 9 | M | M | M | M | M | M | 31.30 | 18.60 |
| 10 | M | M | M | M | M | M | 19.50 | 9.60 |
| 11 | 19.50 | 8.70 | 241.00 | 19.50 | 12.40 | 154.00 | 19.50 | 12.20 |
| 12 | M | M | M | M | M | M | M | M |
| 13 | M | M | M | M | M | M | M | M |
| 14 | 24.00 | 4.60 | 44.00 | 16.00 | 4.40 | 93.00 | M | M |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | M | M | M | M | M | M | M |
| 17 | M | M | M | M | M | M | M | M |
| 18 | 16.00 | 9.40 | 165.00 | 16.00 | 9.60 | 153.00 | 16.00 | 8.60 |
| 19 | M | M | M | M | M | M | M | M |
| 20 | 31.30 | 7.30 | 35.00 | 15.60 | 9.10 | 271.00 | M | M |
| 21 | 20.00 | 6.80 | 76.00 | M | M | M | M | M |
| 22 | M | M | M | M | M | M | M | M |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | M |
| 26 | 15.60 | 9.30 | 45.00 | 15.60 | 9.40 | 151.00 | 15.60 | 9.00 |
| 27 | M | M | M | M | M | M | M | M |
| 28 | 15.60 | 8.50 | 86.00 | 15.60 | 7.80 | 77.00 | 15.60 | 9.80 |
| 29 | M | M | M | M | M | M | M | M |
| 30 | M | M | M | M | M | M | M | M |
| 31 | M | M | M | M | M | M | M | M |
| 32 | 20.00 | 8.90 | 63.00 | 31.50 | 15.00 | 207.00 | 20.00 | 9.10 |
| 33 | 8.00 | 3.90 | 46.00 | 8.00 | 4.30 | 93.00 | 32.00 | 18.50 |
| 34 | M | M | M | M | M | M | M | M |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 12.00 | 6.80 | 213.00 | 12.00 | 7.10 | 204.00 | 20.00 | 12.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | M | M | M | 31.00 | 13.30 | 31.00 | 29.30 | 16.80 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 16.00 | 6.70 | 152.00 | 16.00 | 8.00 | 176.00 | 16.00 | 6.40 |
| 41 | 7.50 | 2.50 | 129.00 | 31.30 | 10.10 | 180.00 | 7.80 | 2.60 |
| 42 | M | M | M | M | M | M | M | M |
| 43 | 8.00 | 1.70 | 206.00 | 31.90 | 8.70 | 185.00 | 16.00 | 2.00 |

| CASE | PP5MC | PP6S | PP6PU | PP6MC | PP7S | PP7PU | PP7MC | PP8S |
|---|---|---|---|---|---|---|---|---|
| 1 | 85.00 | M | M | M | M | M | M | M |
| 2 | M | 2.90 | 2.10 | 413.00 | 32.00 | 1.30 | 67.00 | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | 263.00 | 19.50 | 6.30 | 200.00 | 19.50 | 5.80 | 190.00 | M |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | 219.00 | 15.00 | 5.90 | 133.00 | M | M | M | M |
| 9 | 137.00 | 31.80 | 11.70 | 247.00 | M | M | M | M |
| 10 | 121.00 | 29.30 | 12.60 | 201.00 | 19.50 | 9.80 | 121.00 | 19.50 |
| 11 | 153.00 | M | M | M | M | M | M | M |
| 12 | M | M | M | M | M | M | M | M |
| 13 | M | 31.30 | 7.40 | 157.00 | 31.30 | 8.50 | 105.00 | M |
| 14 | M | 16.00 | 5.10 | 72.00 | M | M | M | M |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | M | M | M | M | M | M | M |
| 17 | M | M | M | M | M | M | M | M |
| 18 | 141.00 | 16.00 | 1.90 | 38.00 | M | M | M | M |
| 19 | M | M | M | M | M | M | M | M |
| 20 | M | 31.30 | 7.30 | 40.00 | M | M | M | M |
| 21 | M | 28.00 | 11.70 | 215.00 | 20.00 | 6.70 | 83.00 | 20.00 |
| 22 | M | M | M | M | M | M | M | M |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | M |
| 26 | 157.00 | 15.60 | 7.90 | 120.00 | M | M | M | M |
| 27 | M | M | M | M | M | M | M | M |
| 28 | 104.00 | 15.60 | 8.60 | 110.00 | M | M | M | M |
| 29 | M | 30.00 | 13.00 | 179.00 | 30.00 | 12.00 | 203.00 | 30.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | M | M | M | M | M | M | M | M |
| 32 | 64.00 | 20.00 | 9.10 | 46.00 | M | M | M | M |
| 33 | 261.00 | 8.00 | 3.10 | 52.00 | 8.00 | 3.70 | 46.00 | M |
| 34 | M | M | M | M | M | M | M | M |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 282.00 | M | M | M | M | M | M | M |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 68.00 | 29.30 | 16.30 | 53.00 | M | M | M | M |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 153.00 | 16.00 | 8.00 | 176.00 | M | M | M | M |
| 41 | 117.00 | 7.80 | 1.90 | 110.00 | M | M | M | M |
| 42 | M | M | M | M | M | M | M | M |
| 43 | 98.00 | 8.00 | 2.00 | 190.00 | M | M | M | M |

| CASE | PP8PU | PP8MC | SPPS | ASPL | D1IOBNT | D2IOBNT | D3IOBNT | D4IOBNT |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | 109.00 | 0.00 | M | M | M | M |
| 2 | M | M | 64.20 | 1.00 | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | M | M | 129.30 | 0.00 | M | M | M | M |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | M | M | 80.00 | M | M | M | M | M |
| 9 | M | M | 87.50 | 0.00 | M | M | M | M |
| 10 | 9.00 | 124.00 | 130.00 | 0.00 | M | M | M | M |
| 11 | M | M | 97.50 | 1.00 | M | M | M | M |
| 12 | M | M | M | M | M | M | M | M |
| 13 | M | M | 93.90 | 3.00 | 0.46 | 0.79 | 0.26 | 0.21 |
| 14 | M | M | 88.00 | 1.00 | 0.14 | 0.17 | 0.21 | 0.19 |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | M | M | M | M | M | M | M |
| 17 | M | M | M | M | M | M | M | M |
| 18 | M | M | 96.00 | 0.00 | M | M | M | M |
| 19 | M | M | M | M | 0.38 | 0.30 | 0.44 | 0.42 |
| 20 | M | M | 78.00 | 0.00 | M | M | M | M |
| 21 | 7.30 | 86.00 | 108.00 | 0.00 | M | M | M | M |
| 22 | M | M | M | M | M | M | M | M |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | M |
| 26 | M | M | 110.00 | 0.00 | M | M | M | M |
| 27 | M | M | M | M | 0.31 | 0.28 | 0.32 | 0.35 |
| 28 | M | M | 109.30 | 0.00 | 0.45 | 0.37 | 0.64 | 0.25 |
| 29 | 14.20 | 191.00 | 120.00 | 0.00 | 0.63 | 1.50 | 0.31 | 0.54 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | M | M | M | M | 0.19 | 0.31 | 0.23 | 0.21 |
| 32 | M | M | 129.50 | 0.00 | M | M | M | M |
| 33 | M | M | 64.00 | 1.00 | M | M | M | M |
| 34 | M | M | M | M | 0.25 | 0.26 | 0.24 | 0.33 |
| 35 | M | M | M | M | M | M | M | M |
| 36 | M | M | 56.00 | 0.00 | M | M | M | M |
| 37 | M | M | M | M | M | M | M | M |
| 38 | M | M | 119.00 | 0.00 | M | M | M | M |
| 39 | M | M | M | M | M | M | M | M |
| 40 | M | M | 96.00 | 0.00 | 0.18 | 0.19 | 0.21 | 0.21 |
| 41 | M | M | 70.3 | M | M | M | M | M |
| 42 | M | M | M | M | M | M | M | M |
| 43 | M | M | 79.90 | 0.00 | M | M | M | M |

| CASE | D5IOBNT | D6IOBNT | D7IOBNT | D8IOBNT | PFJOB | PFEPRJ | PFRPR | PFWO |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 5 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 8 | M | M | M | M | M | M | M | M |
| 9 | M | M | M | M | M | M | M | M |
| 10 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 11 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 12 | M | M | M | M | M | M | M | M |
| 13 | 0.22 | 0.45 | 0.65 | 0.50 | M | M | M | M |
| 14 | 0.18 | 0.16 | M | M | M | M | M | M |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | M | M | M | M | M | M | M |
| 17 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 18 | M | M | M | M | M | M | M | M |
| 19 | 0.39 | 0.34 | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 20 | M | M | M | M | M | M | M | M |
| 21 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 22 | M | M | M | M | M | M | M | M |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | M |
| 26 | M | M | M | M | M | M | M | M |
| 27 | 0.36 | 0.37 | 0.28 | 0.37 | M | M | M | M |
| 28 | 0.34 | 0.37 | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 29 | 0.33 | 0.30 | 0.21 | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | 0.17 | 0.14 | 0.21 | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 32 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 33 | M | M | M | M | M | M | M | M |
| 34 | 0.26 | 0.31 | 0.28 | 0.24 | M | M | M | M |
| 35 | M | M | M | M | M | M | M | M |
| 36 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | 0.18 | 0.15 | M | M | M | M | M | M |
| 41 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |
| 42 | M | M | M | M | M | M | M | M |
| 43 | M | M | M | M | 100.00 | 100.00 | 100.00 | 100.00 |

| CASE | EXTJOB | EXTRPR | EXTEPRJ | EXTWO | COMJOB | COMRPR | COMEPRJ | COMWO |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | 2.00 | 1.00 | 2.00 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 5 | 2.00 | 1.00 | 2.00 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 6 | M | M | M | M | M | M | M | M |
| 7 | 1.00 | 2.00 | 2.00 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 8 | M | M | M | M | M | M | M | M |
| 9 | M | M | M | M | M | M | M | M |
| 10 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 11 | 1.00 | 1.00 | 1.00 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 12 | 1.00 | 1.00 | 1.00 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 13 | M | M | M | M | M | M | M | M |
| 14 | M | M | M | M | M | M | M | M |
| 15 | M | M | M | M | M | M | M | M |
| 16 | M | M | M | M | M | M | M | M |
| 17 | 3.00 | 2.00 | 2.00 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 18 | M | M | M | M | M | M | M | M |
| 19 | 2.00 | 3.00 | 3.00 | 1.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 20 | M | M | M | M | M | M | M | M |
| 21 | 2.00 | 1.00 | 2.00 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 22 | M | M | M | M | M | M | M | M |
| 23 | M | M | M | M | M | M | M | M |
| 24 | M | M | M | M | M | M | M | M |
| 25 | M | M | M | M | M | M | M | M |
| 26 | M | M | M | M | M | M | M | M |
| 27 | M | M | M | M | M | M | M | M |
| 28 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 29 | 2.00 | 3.00 | 2.00 | 4.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 30 | M | M | M | M | M | M | M | M |
| 31 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 32 | 2.00 | 2.00 | 1.00 | 2.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 33 | M | M | M | M | M | M | M | M |
| 34 | M | M | M | M | M | M | M | M |
| 35 | M | M | M | M | M | M | M | M |
| 36 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 37 | M | M | M | M | M | M | M | M |
| 38 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 39 | M | M | M | M | M | M | M | M |
| 40 | M | M | M | M | M | M | M | M |
| 41 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 42 | M | M | M | M | M | M | M | M |
| 43 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 |

Data Base 3

| CASE | BASE | F1MMAU | F2MMAU | F3MMAU | F4MMAU | F5MMAU | F6MMAU | F7MMAU |
|---|---|---|---|---|---|---|---|---|
| 1 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | M | M | M |
| 2 | 12.00 | M | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| 3 | 13.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | M | M |
| 4 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | M | M | 0.00 |
| 5 | 29.00 | M | M | M | M | M | 0.00 | 0.00 |
| 6 | 27.00 | M | M | M | M | M | M | 0.00 |
| 7 | 36.00 | M | 0.00 | 1.00 | 1.00 | 0.00 | M | 0.00 |
| 8 | 41.00 | M | 0.00 | 1.00 | 1.00 | M | M | M |

| CASE | F8MMAU | F9MMAU | F10MMAU | F11MMAU | F12MMAU | F13MMAU | F14MMAU | F15MMAU |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | 0.00 | 1.00 | M | M | M | M | M | M |
| 5 | 0.00 | M | M | M | M | M | M | 1.00 |
| 6 | M | M | 1.00 | 0.00 | 1.00 | 22.00 | 61.00 | M |
| 7 | 1.00 | M | M | M | M | M | M | M |
| 8 | M | M | M | M | M | M | M | M |

| CASE | F16MMAU | F17MMAU | F18MMAU | F19MMAU | F20MMAU | F1MAAU | F21MMAU | F22MMAU |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | 0.00 | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | 0.00 | M | M |
| 4 | M | M | M | M | M | 0.00 | M | M |
| 5 | M | 0.00 | M | M | M | M | M | M |
| 6 | M | M | M | M | M | M | M | M |
| 7 | 2.00 | M | 1.00 | 0.00 | 2.00 | M | M | M |
| 8 | M | M | M | M | M | M | 0.00 | 0.00 |

| CASE | F23MMAU | F24MMAU | F25MMAU | F26MMAU | F27MMAU | F2MAAU | F3MAAU | F4MAAU |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | 0.00 | 0.00 | 0.00 |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | 0.00 | 0.00 | 1.00 |
| 4 | M | M | M | M | M | 0.00 | 0.00 | 0.00 |
| 5 | M | M | M | M | M | M | M | M |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 |

| CASE | F5MAAU | F6MAAU | F7MAAU | F8MAAU | F9MAAU | F10MAAU | F11MAAU | F12MAAU |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | 0.00 | M | M | M | M | M | M | M |
| 4 | M | M | 0.00 | 0.00 | 1.00 | M | M | M |
| 5 | M | 0.00 | 0.00 | 0.00 | M | M | M | M |
| 6 | M | M | 1.00 | M | M | 1.00 | 0.00 | 1.00 |
| 7 | 0.00 | M | 0.00 | 0.00 | M | M | M | M |
| 8 | M | M | M | M | M | M | M | M |

| CASE | F13MAAU | F14MAAU | F15MAAU | F16MAAU | F17MAAU | F18MAAU | F19MAAU | F20MAAU |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | M | M | 0.00 | M | 0.00 | M | M | M |
| 6 | 25.00 | 70.00 | M | M | M | M | M | M |
| 7 | M | M | M | 4.00 | M | 0.00 | 0.00 | 9.00 |
| 8 | M | M | M | M | M | M | M | M |

| CASE | F21MAAU | F22MAAU | F23MAAU | F24MAAU | F25MAAU | F26MAAU | F27MAAU | F1AU |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | 0.10 |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | 0.00 |
| 4 | M | M | M | M | M | M | M | 0.63 |
| 5 | M | M | M | M | M | M | M | M |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | M | M | M |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | M |

| CASE | F2AU | F3AU | F4AU | F5AU | F6AU | F7AU | F8AU | F9AU |
|---|---|---|---|---|---|---|---|---|
| 1 | 9.10 | 8.10 | 2.60 | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | 10.00 | 7.00 | 7.00 | 8.00 | M | M | M | M |
| 4 | 5.75 | 5.50 | 5.00 | M | M | 2.90 | 3.75 | 0.00 |
| 5 | M | M | M | M | 1.40 | 4.60 | 3.62 | M |
| 6 | M | M | M | M | M | M | M | M |
| 7 | 13.00 | 7.00 | 6.50 | 3.20 | M | 5.60 | 4.20 | M |
| 8 | 18.90 | 6.00 | 5.10 | M | M | M | M | M |

| CASE | F10AU | F11AU | F12AU | F13AU | F14AU | F15AU | F16AU | F17AU |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | M | M | M | M | M | 0.13 | M | 0.50 |
| 6 | M | M | M | M | M | M | M | M |
| 7 | M | M | M | M | M | M | 6.50 | M |
| 8 | M | M | M | M | M | M | M | M |

| CASE | F18AU | F19AU | F20AU | F21AU | F22AU | F23AU | F24AU | F25AU |
|---|---|---|---|---|---|---|---|---|
| 1 | M | M | M | M | M | M | M | M |
| 2 | M | M | M | M | M | M | M | M |
| 3 | M | M | M | M | M | M | M | M |
| 4 | M | M | M | M | M | M | M | M |
| 5 | M | M | M | M | M | M | M | M |
| 6 | M | M | M | M | M | M | M | M |
| 7 | 5.50 | 49.00 | 9.00 | M | M | M | M | M |
| 8 | M | M | M | 3.60 | 5.00 | 5.00 | 1.50 | 0.00 |

| CASE | F26AU | F27AU |
|---|---|---|
| 1 | M | M |
| 2 | M | M |
| 3 | M | M |
| 4 | M | M |
| 5 | M | M |
| 6 | M | M |
| 7 | M | M |
| 8 | 1.40 | 7.00 |

Appendix G: I/O Bottleneck Detection Program

```
*****************************************************************
**************** I/O BOTTLENECK DETECTION PROGRAM ***************
*****************************************************************
*                                                               *
*  Version: 5.1    Date of last revision: 10 Jul 90             *
*                                                               *
*  File name:  IOBNDTCT                                         *
*                                                               *
*  ORIGINAL IDEA AND PROGRAM BY DAVE JOHNSTON, OL-AFESC         *
*                                                               *
*  CURRENT PROGRAM BY CAPT RENO LIPPOLD, AFIT/LSG               *
*                                                               *
*****************************************************************

*Selecting the workstation as output for print statements.
SELECT WS

*Clears the screen and moves the cursor to the upper left.
PRINT PAGE
PRINT:PRINT:PRINT
PRINT "  Welcome to the input/output (I/O) bottleneck detector"
PRINT "  program."
PRINT
PRINT "  This program writes 10 small records to a file on each "
PRINT "  disk drive - one record at a time.  The times to write"
PRINT "  each record are recored and the average times are     "
PRINT "  calculated and displayed."
 PRINT:PRINT:PRINT
PRINT "  To continue, press <Enter>.   To Exit Press PF16."
 PRINT:PRINT:PRINT
STOP

*Dimensions for variables.
DIM RECVR$(20) 16, AVGTIME(20), DATETIME$ 45, BEGINTIME$(10,20) 16
DIM ENDTIME$(10,20) 16, BEGINHRS%(10,20), ENDHRS%(10,20)
DIM BEGINMIN%(10,20),ENDMIN%(10,20),BEGINSEC(10,20),ENDSEC(10,20)
DIM CHNGHRS%(10,20),CHNGMIN%(10,20),CHNGSEC(10,20),SUMCHNG(10,20)

*Call READVTOC VSSUB to determine the system configuration.
MAXVOL% = 20 /*Won't work if you have over 20 volumes mounted*/
CALL "READVTOC" ADDR("V",1%,MAXVOL%,RECVR$(),NUMVOL%)

*Prints out mounted volumes for verification.
PRINT PAGE
PRINT:PRINT:PRINT
PRINT "   The disk drives currently mounted are:"
PRINT
FOR I = 1 TO NUMVOL%
```

```
    PRINT "     "; STR(RECVR$(I),1,6)
NEXT I
PRINT
PRINT "    To continue press <Enter>.  To Exit press PF16."
PRINT:PRINT:PRINT
STOP

*Sets up files (UFB - user file blocks).
SELECT #1,"TEMP",CONSEC,RECSIZE=40
SELECT #2,"RESULTS",PRINTER,RECSIZE=80

*Allocates space on each volume for the dummy files.
FOR I = 1 TO NUMVOL%
    CURVOL$ = STR(RECVR$(I),1,6)
    OPEN NODISPLAY #1,OUTPUT,SPACE=10,FILE="TEMP",                  !
    LIBRARY="TEMPDATA",VOLUME=CURVOL$
    CLOSE #1
NEXT I
PRINT PAGE
PRINT:PRINT:PRINT
PRINT "    File space has been allocated."
*Need a delay here.

PRINT PAGE
PRINT:PRINT:PRINT

*****************************************************************
*Loops for writing the records to the dummy files.
FOR I = 1 TO 10
    PRINT "    Writing record ";I;" to all disk drives."
    FOR J = 1 TO NUMVOL%
        CURVOL$=STR(RECVR$(J),1,6)
        BEGINTIME$(I,J) = TIME
        OPEN NODISPLAY #1, EXTEND,FILE="TEMP",LIBRARY="TEMPDATA",!
        VOLUME=CURVOL$
        WRITE #1,"1 2 3 4 5 6 7 8 9 10"
        CLOSE #1
        ENDTIME$(I,J) = TIME
    NEXT J
NEXT I

*****************************************************************
*Scratches the dummy files on all volumes.
PRINT PAGE:PRINT:PRINT
PRINT "    Scratching dummy files."
FOR I = 1 TO NUMVOL%
    CURVOL$ = STR(RECVR$(I),1,6)
    CALL "SCRATCH"  ADDR("F", "TEMP    ","TEMPDATA",CURVOL$,R%)
NEXT I

R% = 1 /*Dummy expression to avoid compile errors*/
```

```
*Prints time matrices.
*FOR I = 1 TO NUMVOL%
*     FOR J = 1 TO 5
*        CURVOL$ = STR(RECVR$(I),1,6)
*        PRINT CURVOL$;": ";BEGINTIME$(J,I);"   ";ENDTIME$(J,I)
*     NEXT J
*     STOP
*NEXT I
*STOP

*Creating of the beginning and ending hrs, minutes, and seconds
FOR I = 1 TO 10
    FOR J = 1 TO NUMVOL%
        CONVERT STR(BEGINTIME$(I,J),1,2) TO BEGINHRS%(I,J)
        CONVERT STR(ENDTIME$(I,J),1,2) TO ENDHRS%(I,J)
        CONVERT STR(BEGINTIME$(I,J),3,2) TO BEGINMIN%(I,J)
        CONVERT STR(ENDTIME$(I,J),3,2) TO ENDMIN%(I,J)
        CONVERT STR(BEGINTIME$(I,J),5,4) TO BEGINSEC(I,J)
        CONVERT STR(ENDTIME$(I,J),5,4) TO ENDSEC(I,J)
    NEXT J
NEXT I

*Creating matrices of the changes in hrs, minutes and seconds.
FOR I = 1 TO 10
    FOR J = 1 TO NUMVOL%
        CHNGHRS%(I,J)=ENDHRS%(I,J)-BEGINHRS%(I,J)
        CHNGMIN%(I,J)=ENDMIN%(I,J)-BEGINMIN%(I,J)
        CHNGSEC(I,J)=ENDSEC(I,J)-BEGINSEC(I,J)
    NEXT J
NEXT I

*Creating a matrix of the sum of the above changes (in seconds)
FOR I = 1 TO 10
    FOR J = 1 TO NUMVOL%
        SUMCHNG(I,J) = CHNGHRS%(I,J)*3600 + CHNGMIN%(I,J)*60 +    !
        CHNGSEC(I,J)/100
    NEXT J
NEXT I

*Finding the averages of the access times for each disk.
FOR I = 1 TO NUMVOL%
    AVGTIME(I) = (SUMCHNG(1,I) + SUMCHNG(2,I) + SUMCHNG(3,I) +    !
    SUMCHNG(4,I) + SUMCHNG(5,I) + SUMCHNG(6,I) + SUMCHNG(7,I) +   !
    SUMCHNG(8,I) + SUMCHNG(9,I) + SUMCHNG(10,I) ) / 10
NEXT I

*Retrieving date and time information to be printed in the report.
CALL "DATE" ADDR("HL",DATETIME$)



*Printing the results of the test.
```

```
PRINT PAGE
PRINT
PRINT "    RESULTS OF DISK I/O BOTTLENECK DETECTOR"
PRINT
PRINT "    ";DATETIME$
PRINT
PRINT "    VOLUME    AVERAGE WRITE"
PRINT "    NAME      TIME in seconds"
PRINT
FOR I = 1 TO NUMVOL%
    PRINT "    "; STR(RECVR$(I),1,6);":  ";AVGTIME(I)
NEXT I
PRINT
PRINT "    Press <Enter> to continue."
PRINT:PRINT:PRINT
STOP


PRINT PAGE:PRINT:PRINT:PRINT
PRINT "   To send the results to a print file press PF1."
PRINT
PRINT "   Otherwise, press <Enter> to end the program."
PRINT:PRINT:PRINT
STOP
PRINT PAGE
PRINT:PRINT:PRINT
PRINT "   PROGRAM COMPLETE."
END



************************ SUBROUTINES ***************************

* Allows program temination upon pressing PF 16.
DEF FN'16
PRINT:PRINT:PRINT
PRINT "PROGRAM TERMINATED BY USER."
END

*Sends the results of the test to the printer after pressing PF1.
DEF FN'1
SELECT PRINTER
PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
PRINT
PRINT "            RESULTS OF DISK I/O BOTTLENECK DETECTOR"
PRINT
PRINT "            ";DATETIME$
PRINT
PRINT "            VOLUME    AVERAGE WRITE"
PRINT "            NAME      TIME in seconds"
PRINT
FOR I = 1 TO NUMVOL%
```

```
    PRINT "              "; STR(RECVR$(I),1,6);":  ";AVGTIME(I)
NEXT I
PRINT
SELECT WS
PRINT PAGE
PRINT:PRINT:PRINT
PRINT "    The results have been sent to your user print library"
PRINT "    #XXXPRT. "
PRINT:PRINT:PRINT
PRINT "    Press <Enter> to finish the program."
PRINT:PRINT:PRINT
STOP
PRINT PAGE
PRINT:PRINT:PRINT
PRINT "    PROGRAM COMPLETE."
END
```

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## Vita

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The purpose of this research is to collect and analyze information relating to system performance of the Work Information Management System. Information on system performance analysis and tuning is consolidated by means of literature review and interviews of experts. A combination tutorial and questionnaire is developed to collect the data. Two new measurement techniques are developed. Data are collected and summarized on system performance knowledge and involvement. Data are collected on system parameter settings and configuration, external factors related to system performance, and levels of system performance. The data are analyzed to provide a description of current performance conditions, to establish a baseline for future comparisons, and to determine or confirm relationships between performance related variables. Information is collected in fifteen areas of performance from forty-two bases. The research shows larger system memory and unfixed Sharer buffers are strongly related to better system performance. A list of suggested parameter settings is provided. Recommendations for future research in this area are presented.

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